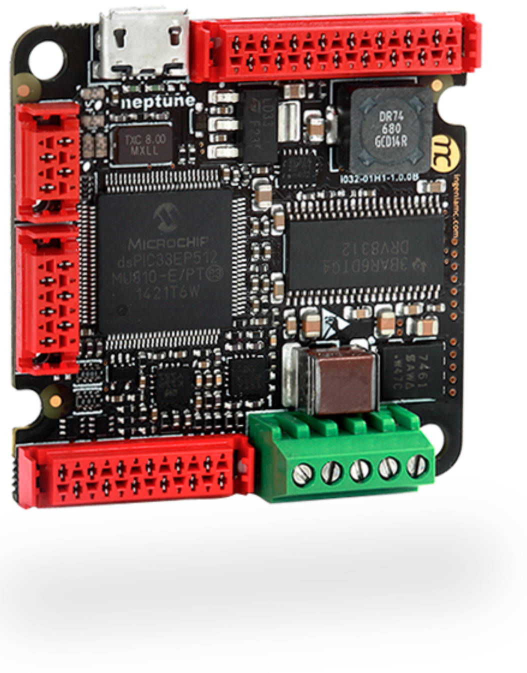
Neptune Product Manual



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For the most up to date information visit the online manual.

INGENIA-CAT, S.L.

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1 Table of Contents

2 General Information

2.1 Manual revision history

Revision	Release Date	Changes	
v1	January 2015	First version	
v2	September 2015	Major update	
v3	March 2016	Minor changes and aesthetic improvements	
v4	April 2016	Added EtherCAT information. Structure improvements.	
v5	November 2016	Minor improvements.	
v6	March 2017	Aesthetics and structure improvement. Wiring information improved.	
v7	May 2017	Improved PDF export format.	
v8	February 2020	Minor corrections. Added PDF automatic exporter.	Download PDF

For the most up to date information use the online Product Manual. Please refer to product hardware revisions page for information on previous hardware revisions and changes.

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3 Safety Information

3.1 About this manual

Read carefully this chapter to raise your awareness of potential risks and hazards when working with the Neptune Servo Drive.

To ensure maximum safety in operating the Neptune Servo Drive, it is essential to follow the procedures included in this guide. This information is provided to protect users and their working area when using the Neptune Servo Drive, as well as other hardware that may be connected to it. Please read this chapter carefully before starting the installation process.

3.2 Warnings

The following statements should be considered to avoid serious injury to those individuals performing the procedures and/or damage to the equipment:

- To prevent the formation of electric arcs, as well as dangers to personnel and electrical contacts, never connect/disconnect the Neptune Servo Drive while the power supply is on.
- Disconnect the Neptune Servo Drive from all power sources before proceeding with any possible wiring change.
- After turning off the power and disconnecting the equipment power source, wait at least 10 seconds before touching any parts of the controller that are electrically charged or hot.

3.3 Precautions

The following statements should be considered to avoid serious injury to those individuals performing the procedures and/or damage to the equipment:

- The Neptune Servo Drive components temperature may exceed 100 ºC during operation.
- Some components become electrically charged during and after operation.
- The power supply connected to this controller should comply with the parameters specified in this document.
- When connecting the Neptune Servo Drive to an approved power source, do so through a line that is separate from any possible dangerous voltages, using the necessary insulation in accordance with safety standards.
- High-performance motion control equipment can move rapidly with very high forces. Unexpected motion may occur especially during product commissioning. Keep clear of any operational machinery and never touch them while they are working.
- Do not make any connections to any internal circuitry. Only connections to designated connectors are allowed.
- All service and maintenance must be performed by qualified personnel.
- Before turning on the Neptune Servo Drive, check that all safety precautions have been followed, as well as the installation procedures.

4 Product Description

Neptune is a high performance closed loop servo drive controller suitable for DC brushed, voice coils and brushless motors.

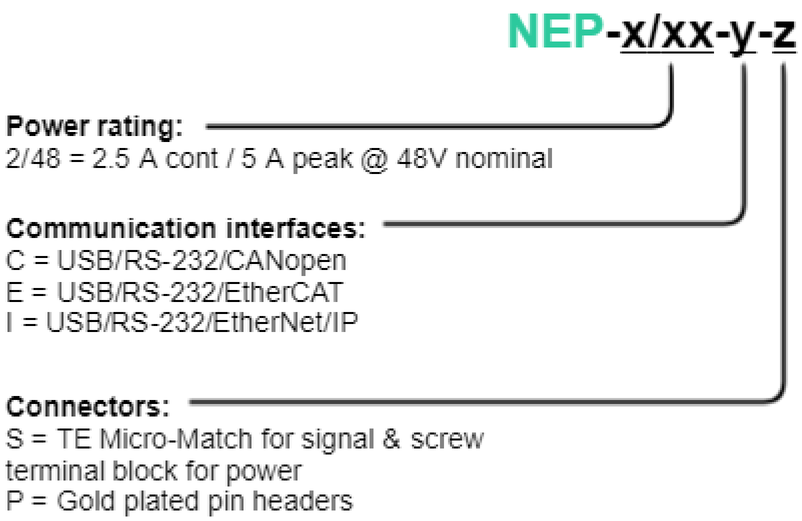
Its compact design (40 mm x 40 mm) includes CANopen/EtherCAT, RS-232 and USB communication ports, enabling thus a wide choice of interfacing methods. Its extended nominal voltage range from 9 V to 48 V with a single supply and current up to 2.5 A continuous allows its use in several applications, and the small footprint and the needless of an external heatsink allow the controller to be a valid OEM for critical-size applications.

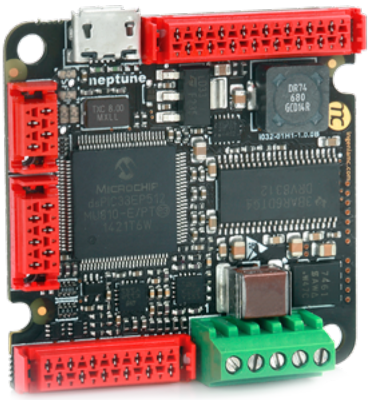
The Neptune Digital Servo Drive has been designed with efficiency in mind. It incorporates cutting-edge MOSFET technology as well as optimized control algorithms to provide the perfect trade-off between EMIs and efficiency. In addition its ultra-low PWM deadtime (<10 ns) provides great control stability in velocity and position applications.

Neptune Servo Drive is provided with several 24V tolerant general purpose inputs and outputs with 5V TTL levels. They are fully protected against short circuits and overvoltage and can be interfaced in industrial environments. By using these inputs and outputs it is possible to implement alarm signals, connect digital sensors, activate external devices (motor brake, LEDs, actuators, solenoids, etc.). Some of the digital and analog inputs can also be used as command / target sources.

Neptune includes many passive and active protections to ensure its safe operation and easy integration.

4.1 Neptune part numbering



Ordering part number	Status	Image
NEP-2/48-C-S	ACTIVE	
NEP-2/48-C-P	ON DEMAND	-
NEP-2/48-E-S	ACTIVE	

4.2 Specifications

Electrical and power specifications		
Part number →	**NEP-2/48-y-S**	**NEP-2/48-y-P**
Nominal power supply voltage	9 V_{DC} to 48 V_{DC}	
Maximum continuous power supply voltage	50 V_{DC}	
Transient peak voltage	60 V_{DC} @ 100 ms	
Logic supply voltage	Not needed, supplied from Power supply voltage	
Internal DC bus capacitance	22 µF	

Minimum motor inductance	100 µH	
Nominal phase continuous current	2.5 A_{RMS} (50°C air temperature, no heatsink)	
Maximum phase peak current	5 A_{RMS} (2 s)	
Current sense range	± 6.3 A	
Current sense resolution	12.28 mA/count	
Shunt braking transistor	No	
Cold plate	No	
Power connectors	Pluggable terminal block 2.54 mm pitch	Pin header 2.54 mm pitch, 5.84 mm length
Standby power consumption	1 W (max). 2 W EtherCAT version (NEP-2/48-E-z)	
Efficiency	> 95% at the rated power and current	
Motion control specifications		
Motion control core	Ingenia E-Core with EMCL2.	
Supported motor types	• Rotary brushless (trapezoidal and sinusoidal) • Linear brushless (trapezoidal and sinusoidal) • DC brushed • Rotary voice coil • Linear voice coil	
Power stage PWM frequency	40 kHz (default) 80 kHz (alternative PWM frequency, configurable)	
Current sensing	On phases A and B (phase C generated internally). Accuracy is ± 1% full scale. 10 bit ADC resolution. Hall sensor current measurement. Neptune is not suitable for environments with high magnetic fields such as close to a motor. Current noise will be observed.	

Sensors for commutation (brushless motors)	• Digital Halls (Trapezoidal) • Analog Halls (Sinusoidal / Trapezoidal) • Quad. Incremental encoder (Sinusoidal / Trapezoidal) • PWM encoder (Sinusoidal / Trapezoidal) • Analog potentiometer (Sinusoidal / Trapezoidal)
Sensors supported for servo loops	• Digital halls • Analog halls • Quad. Incremental encoder • PWM encoder • Analog potentiometer • DC tachometer
Supported target sources	• Network communication – USB • Network communication – CANopen • Network communication – RS-232 • Network communication – EtherCAT • Standalone (execution from Internal EEPROM memory) • Analog input (±10 V or 0 to 5 V) • Step and Direction (Pulse and direction) • PWM command • Encoder follower / Electronic Gearing
Inputs/outputs and protections	
Inputs and Outputs	• 2 x non isolated single ended digital inputs. GPI1, GPI2 (5 V TTL logic, 24V tolerant). • 2 x non isolated high speed differential digital inputs. HS_GPI1 Pulse, HS_GPI2 Direction (5V logic, 24V tolerant). • 1 x (±10 V) differential analog input (12 bits). AN_IN2. (24 V tolerant). • 1 x 0 V... 5 V single ended analog input (12 bits). AN_IN1. (24 V tolerant). • 2 x Open open drain digital outputs with a weak pull-up to 5 V. (24V tolerant and 1 A short-circuit and overcurrent rugged). • 1 x 5 V output supply for powering external circuitry (up to 200 mA).

Protections	• User configurable:
	    • Bus over-voltage
	    • Bus under-voltage
	    • Over-temperature
	    • Under-temperature
	    • Over-current
	    • Overload (I^2t)
	• Short-circuit protections:
	    • Phase-GND
	    • Phase-DC bus
	    • Phase-phase
	• Mechanical limits for homing functions.
	• Hall sequence/combination error.
	• ESD protections in all inputs, outputs, feedbacks and communications.
	• EMI protections (noise filters) in all feedbacks and motor connections.
	• Inverse polarity supply protection: A P-Channel MOSFET provides protection against polarity inversion.
	• High power transient voltage suppressor for short braking (600 W peak TVS diode).

Motor brake	Motor brake output through GPO1 or GPO2. Up to 24 V and 1 A.
Communications	
USB	µUSB (2.0) connector. The board can be supplied from USB for configuration purposes but will not power the motor.
Serial	RS-232 non-isolated.
CANopen	Available. Non-isolated. 120Ω termination not included on board. CiA-301, CiA-305 and CiA-402 compliant.
EtherCAT	Available.
Environmental and mechanical specifications	
Ambient air temperature	• -25 ºC to +50 ºC full current (operating). • +50 ºC to +100 ºC current derating (operating). • -40 ºC to +125 ºC (storage).
Maximum humidity	5% - 85% (non-condensing)
Dimensions	40 mm x 40 mm x 15 mm
Weight (exc. mating connectors)	20 g

4.3 Hardware revisions

Hardware revision*	Description and changes
1.0.0B	First product demo.
1.0.1R	First product release. Changes from previous version: • Minor manufacturing improvements. • Increased minimum absolute system voltage to 8 V to ensure integrated power supply performance at all ranges. • Assembly slots slightly redefined to improve assembly. • Increased default PWM frequency to 80 kHz to target low inductance motors. • Increased over-current range.

Identifying the hardware revision

Hardware revision is screen printed on the board.

4.4 Power and current ratings

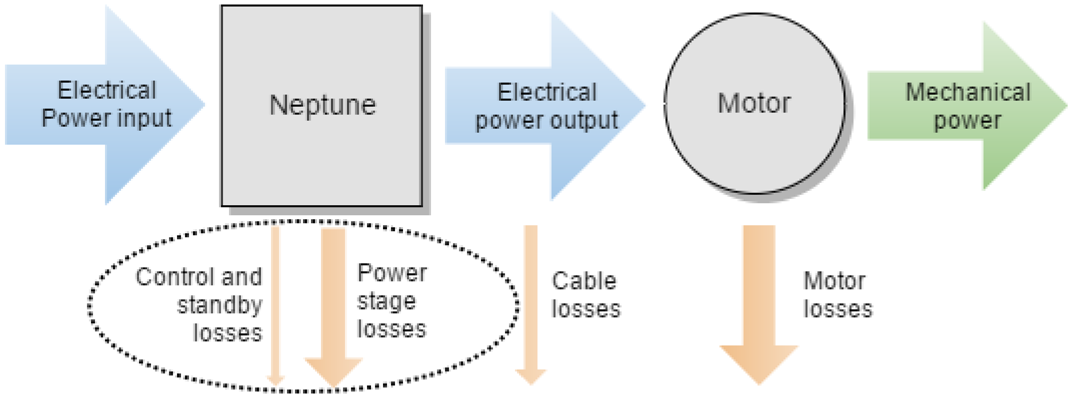
Neptune is capable of providing the nominal current from -40°C to 50°C ambient air temperature without the need of any additional heatsink or forced cooling system. From 50°C to 100°C of ambient temperature a current derating is needed.

Excessive power losses lead to over temperature that will be detected and cause the drive to turn off. The system temperature is available in E-Core registers and is measured on the power stage. The temperature parameter that can be accessed from USB 2.0, CAN or RS232 interface does not indicate the air temperature. Above 110°C the Neptune automatically turns off the power stage and stay in fault state avoiding any damage to the drive. A Fault LED will be activated and cannot be reset unless temperature decreases.

Drive safety is always ensured by its protections. However, power losses and temperature limit the allowable motor current.

Some parts of the Neptune exceed 100°C when operating, especially at high load levels.
Do not touch the Neptune when operating and wait at least 5 minutes after turn off to allow a safe cool down.

Following figure shows the basic power flow and losses in a servo drive system.

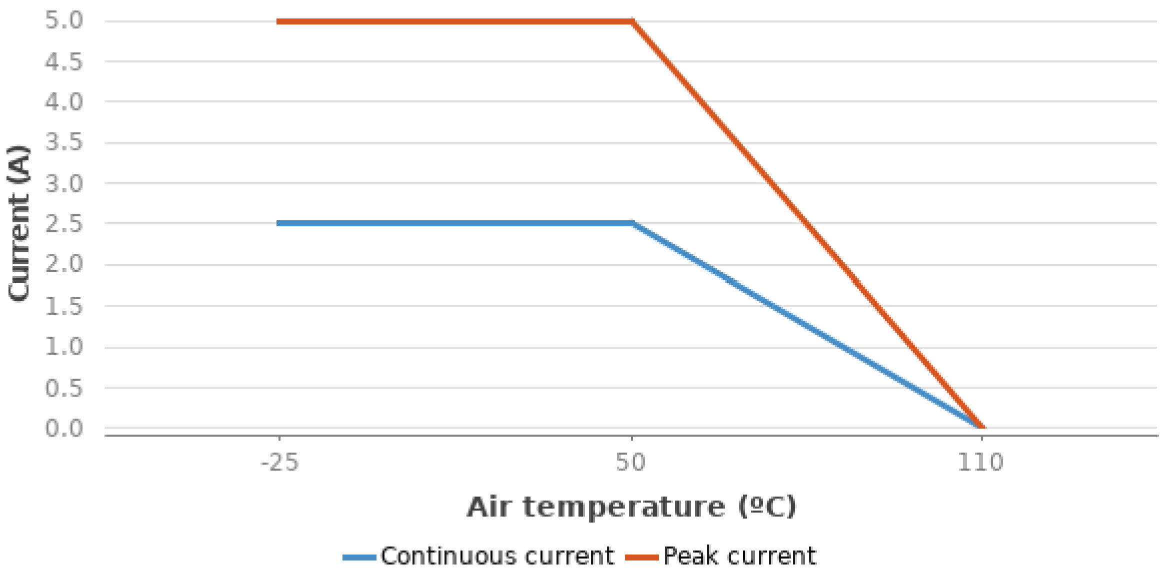


4.4.1 Current ratings

The Neptune Servo Drive has no cold plate, so the board itself is the heatsink. Power losses cause the drive to increase its temperature according to:

$$T_P \approx T_A + P_{LOSS} \cdot Z_{\theta PA}$$

Power losses have a positive correlation with the motor RMS current. For this reason, when the ambient temperature rises above 50 °C, the output current must be limited to avoid an excessive drive temperature (T_P< 100°C).



Current derating

The current derating graph is only indicative and is based on thermal tests performed in a climatic room where there was enough room for natural air convection. Each application may reach different ratings depending on the installation, ventilation or housing. Current derating is only a recommendation and is not performed automatically by the drive.

4.4.2 Dynamic application (non-constant current)

The Neptune has a great thermal inertia that allows storing heat during short power pulses (exceeding nominal current) without overpassing the maximum temperature. This allows achieving high peak current ratings without need of additional heatsink.

For most systems where the cycle time is shorter than 3 τ (thermal time constant) the equivalent current can be calculated as the quadratic mean of the current during the full cycle. The load cycle can be simplified as different constant currents during some times:

$$I_{eq} = \sqrt{\frac{t_1 \cdot I_1^2 + t_2 \cdot I_2^2 + \cdots + t_n \cdot I_n^2}{t_1 + t_2 + \cdots + t_n}}$$

$$T = t_1 + t_2 + \cdots + t_n$$

Where:

T is the full cycle period.

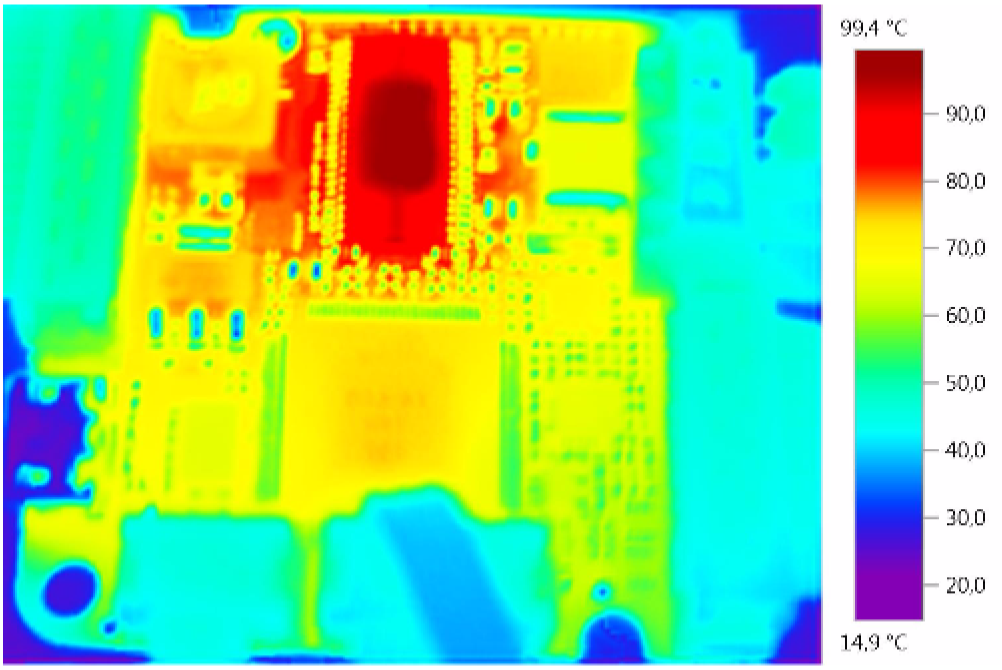
$\mathbf{I_1}$ is the current during t_1

$\mathbf{I_2}$ is the current during t_2

$\mathbf{I_n}$ is the current during t_n

4.4.3 System temperature

Next thermal image shows an example of the heat distribution in a the Neptune. The test has been performed at maximum load and air temperature with a 3 phase application.



> **The drive is getting hot even at 0 current!**
>
> This is normal. Neptune power stage includes high power MOSFET transistors which have parasitic capacitances. Switching them fast means charging and discharging those capacitors thousands of times per second which results in power losses and temperature increase even at 0 current!
>
> **Recommendation: when motor is off, exit motor enable mode which will switch off the power stage.**

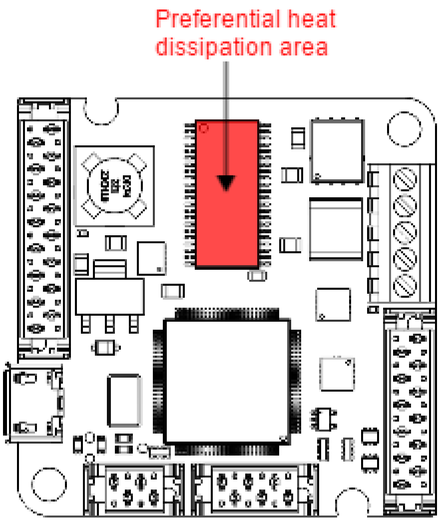
4.4.4 Improving heat dissipation with a heatsink

The Neptune uses the whole PCB as a heatsink by providing preferential heat path from the power stage to the whole board ground planes.

However in some cases, to improve the heat dissipation, a small heatsink can be attached to the power stage block. Also it is possible to mount it on a cooling plate.

In order to do that:

- Provide thermal dissipation in the area indicated on the figure below.
- Use a thermal interface material between the heatsink and the power stage (to ensure good contact and minimize mechanical stress to the package). Double sided heat transfer tapes are recommended. Like Bergquist Bond-Ply 100 BP100-0.005-00-1112.
- Avoid touching any live part such as capacitors with the heatsink.
- This a delicate process, do it with the drive totally unpowered and contact Ingenia engineers for further assistance.



Following are a small heatsink and a recommended thermal interface material for the Neptune.

Manufacturer	PN	Datasheet	Picture
Wakefield Solutions	651-B	Dimensions	

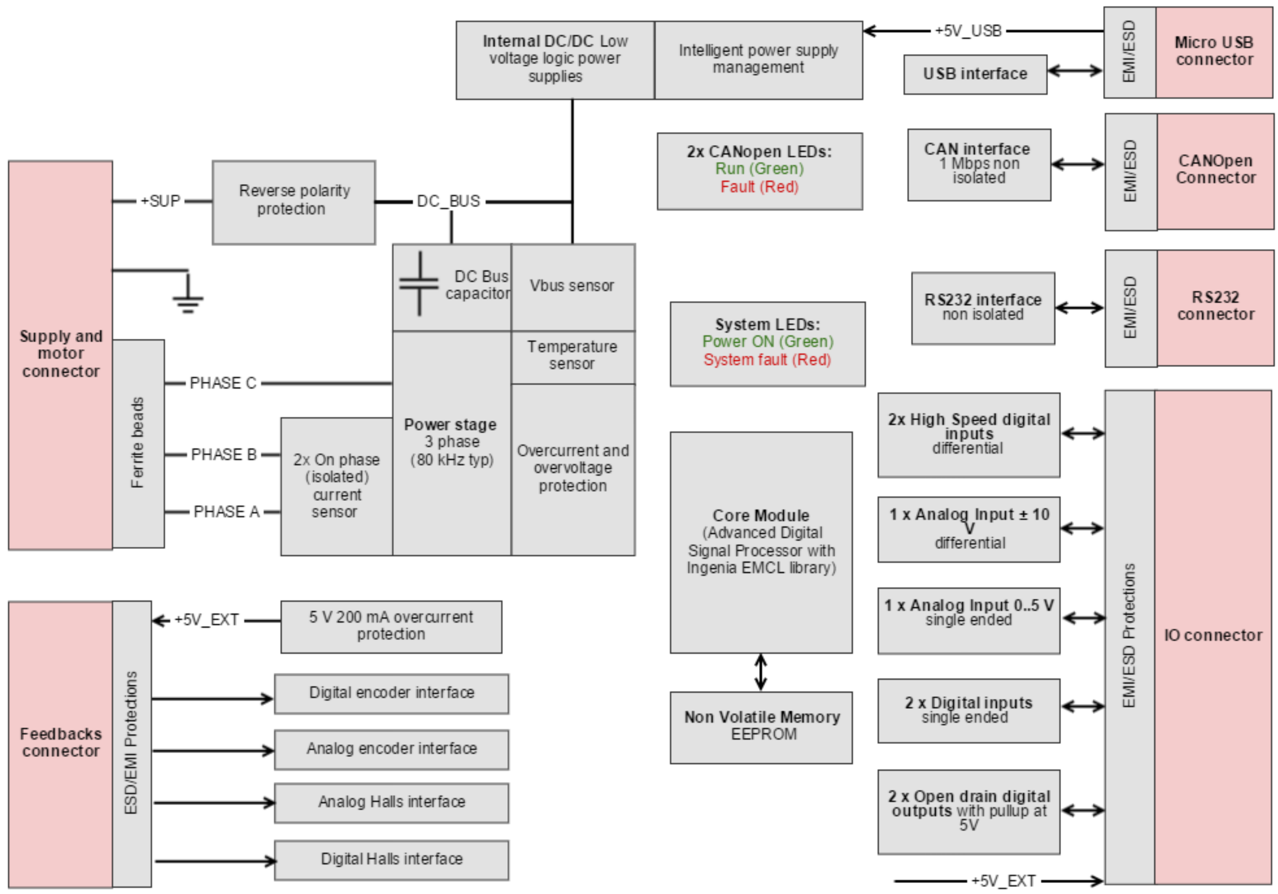
Manufacturer	PN	Datasheet	Picture
Bergquist	BP100-0.005-00-1112	Application guide	

Assembly recommendations for best heat dissipation

- Always allow natural air convection by ensuring ≥ 10 mm air space around the drive.
- Place the Neptune in vertical position.
- If housed, use a good thermal conductivity material such as black anodized aluminum. Placing the drive in a small plastic package will definitively reduce its temperature range.
- Temperature range can be increased by providing forced cooling with a fan or by placing a thermal gap pad on top of the board. Always ensure electrical isolation between live parts and the heatsink.

4.5 Architecture

Following figure shows a simplified hardware architecture of the Neptune.

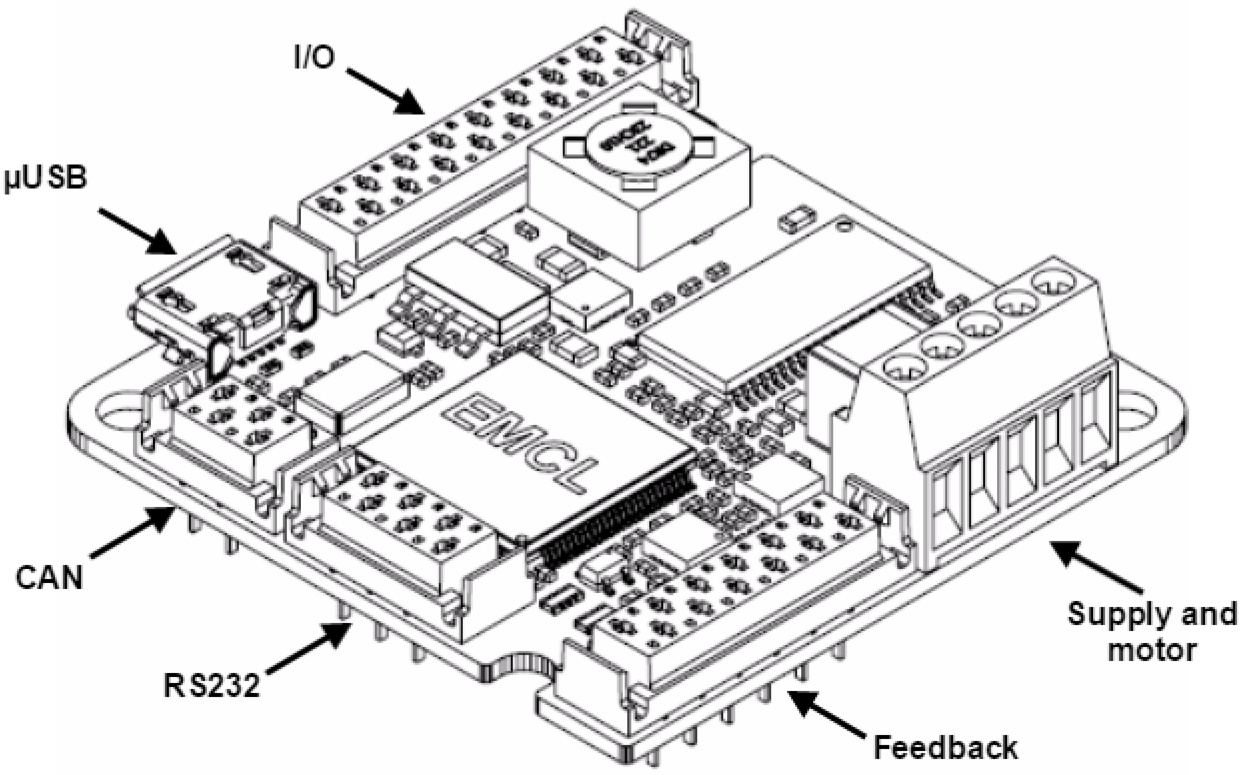


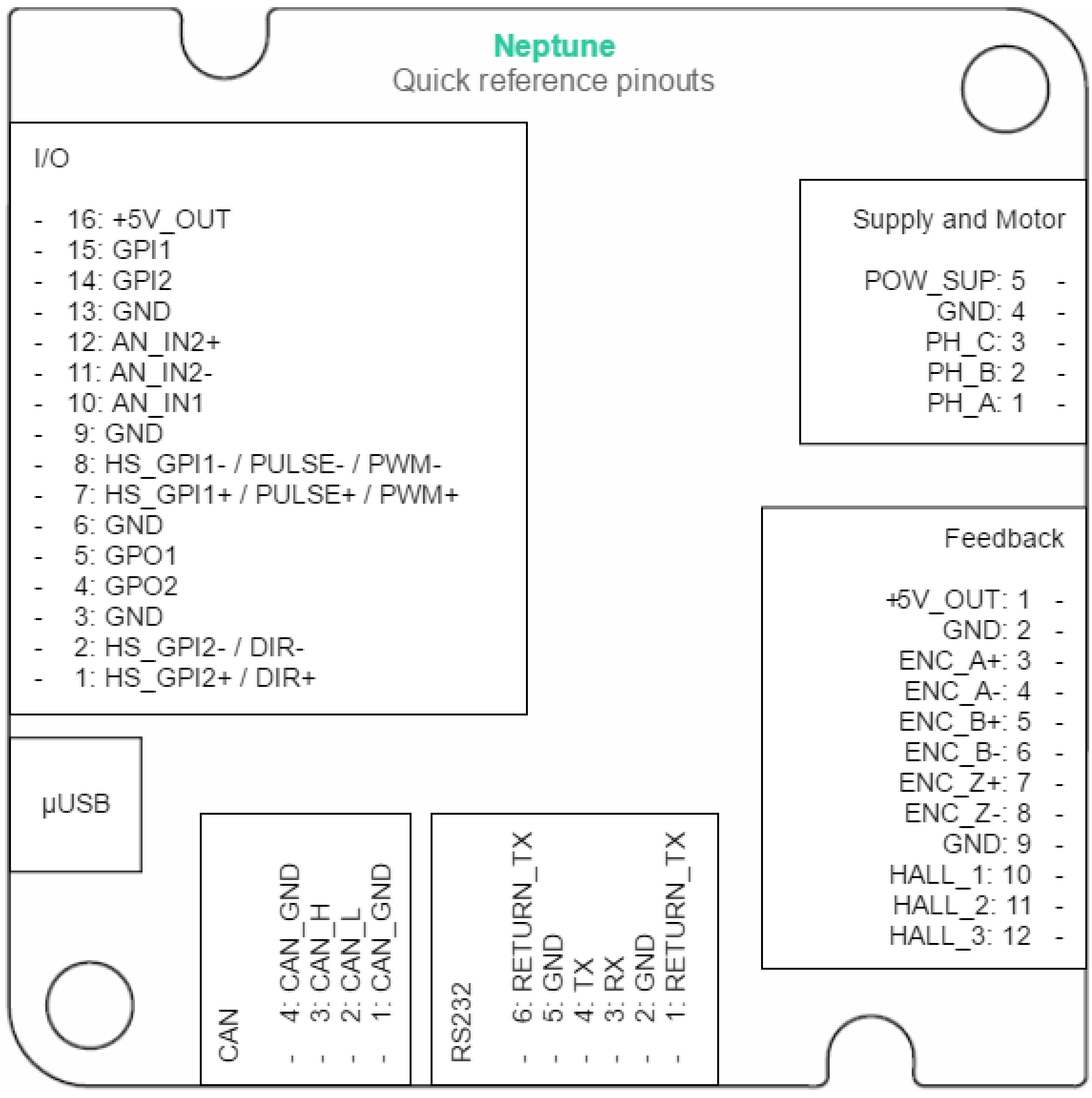
5 Connectors Guide

This chapter details the Neptune Servo Drive connectors and pinout. Three Neptune options are detailed:

- Neptune with TE Micro-Match for signal & screw terminal block for power (NEP-x/xx-y-S).
- Neptune with gold plated pin headers (NEP-x/xx-y-P).
- Neptune with EtherCAT interface (NEP-x/xx-E-z).

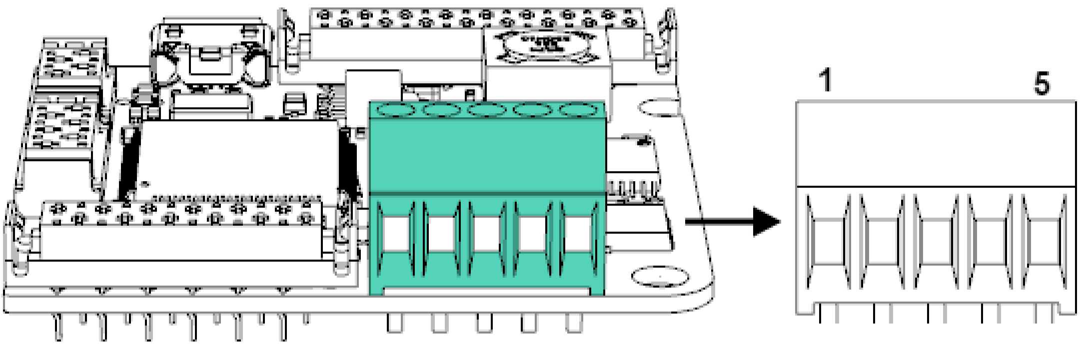
5.1 Connectors position and pinout of Neptune with terminals (NEP-x/xx-y-S)





5.1.1 Supply and motor connector

P1 Connector



5 positon 2.54 mm pitch screw terminal block. TE Connectivity 282834-5.

Pin	Signal	Function
1	PH_A	Motor phase A (Positive for DC and voice coils)
2	PH_B	Motor phase B (Negative for DC and voice coils)
3	PH_C	Motor phase C (Do not connect for DC and voice coils)
4	GND	Power supply Ground (Supply negative)
5	POW_SUP	Power supply positive

Notes

- Dimension the wiring according to the application current ratings. Higher section is always preferred to minimize resistance and wire self-heating.
- Recommended wire section:
    - Stranded wire: 0.25 mm^2 ~ 0.75 mm^2
    - Solid wire: 0.25 mm^2 ~ 1 mm^2
- For wiring information, see motor and power supply wiring sections.

Using cables > 1 mm^2

For cables with a wire gauge between 0.2 mm and 1.6 mm^2, you can use a tab insulated crimp terminal

Crimp terminals

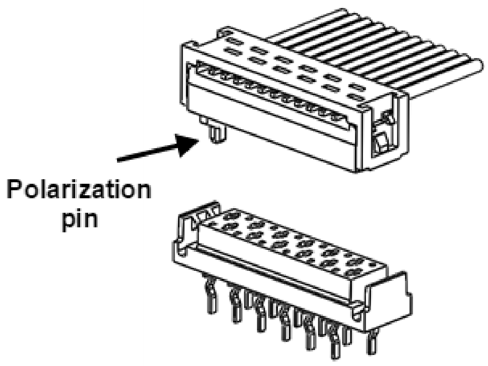
Description	Wire pin terminal connector 0.2 - 1.6 mm^2 (16-22 AWG)

Image	
Part number	TE Connectivity - 165446.
Distributor codes	Digi-Key A112603-ND
Notes	
• Note that overall diameter of insulated crimp terminals exceeds the connector pitch. Therefore it is not recommended to use more than 3 crimped terminals.	

5.1.2 Micro-Match connectors mating

Most Neptune Servo Drive signal connections are based in TE Micro-Match connectors. Two different wiring options can be used **ribbon cable** and **multi-core crimped cable**.

5.1.2.1 Ribbon cable

Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch
Image	
Cable	
Use 0.5 mm² (24 AWG) flat cable.	

Easy wiring

Ribbon cable is the easiest and lowest cost option.

For some applications, the fastest and reliable option is connecting the flat cable directly to the sensor, feedback or IO pins by means of a heat shrink solder sleeve.

Wiring accessory: wire to wire solder sleeve	
Description	Wire to Wire Solder Sleeve Heat shrinkable. Can be used to reliably connect flat Micro-Match wires to specific sensor, feedback or other thin wires.
Image	
TE	B-155-9001
Distributor code	Digi-Key A104848-ND

5.1.3 Multi-core crimped cable

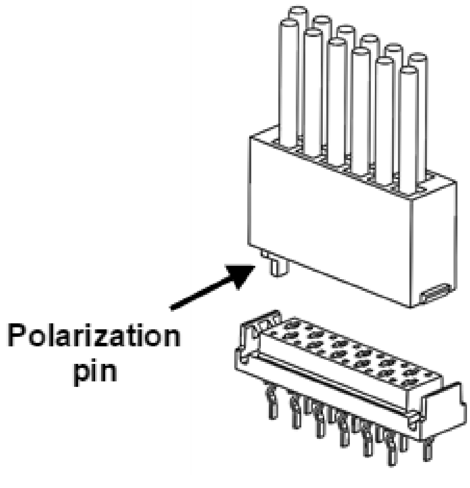
Multi-core crimped cable mating	
Description	TE Micro-Match housing connector 1.27 mm pitch
Image	
Crimp terminals	
Description	Crimp terminal, male, 20-24 AWG

Image	
Part number	TE Connectivity 1-338097-1
Distributor codes	Farnell 1291807 Digi-Key A99491CT-ND Mouser 571-1-338097-1
Cable	
Use 0.2 ~ 0.5 mm² (20 ~24 AWG) flexible wires.	

Clean wiring

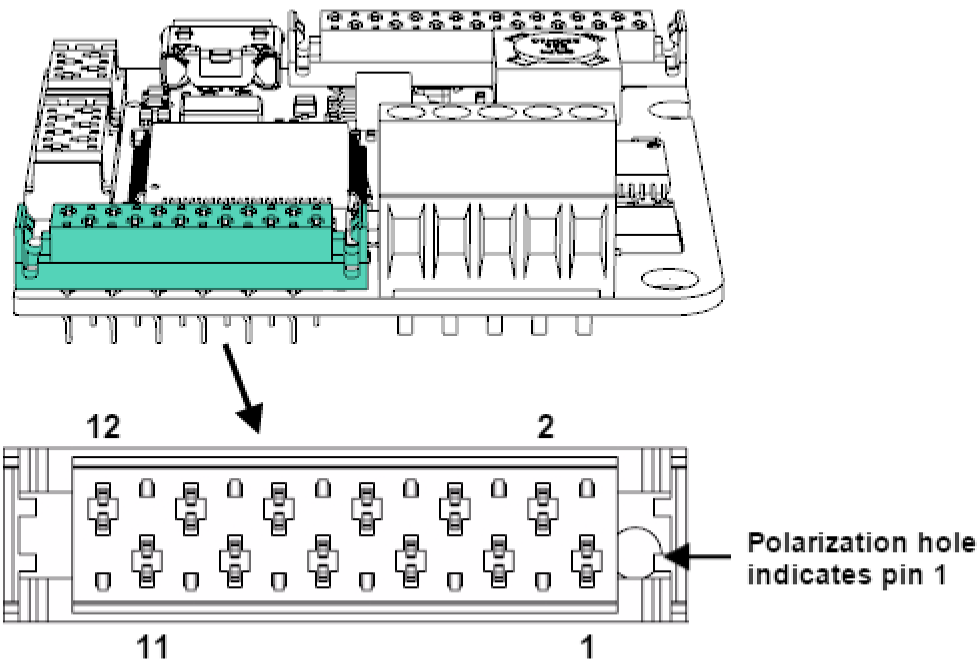
Crimped single cables makes wiring cleaner and is a preferred option for volume applications.

Mechanical fixation for non-connected pins

Main mechanical subjection is provided by the fastening of male and female electrical pins. In order to increase mechanical subjection in applications where not all the pins are connected, it is important to put **crimp terminals also in the pins without cable**.

5.1.4 Feedback connector

P2 Connector



12 pin 1.27 mm pitch TE Micro-Match 1-338068-2 connector.

Pin	Signal	Function
1	+5V_OUT	+5V 200mA max supply for feedbacks (shared with I/O connector)
2	GND	Ground connection
3	ENC_A+	Single ended digital encoder: A input Differential digital encoder: A+ input
4	ENC_A-	Differential Encoder: A- input
5	ENC_B+	Single ended digital encoder: B input Differential digital encoder: B+ input
6	ENC_B-	Differential Encoder: B- input

7	ENC_Z+	Single ended digital encoder: Index input Differential digital encoder: Index+ input
8	ENC_Z-	Differential Encoder: Index- input
9	GND	Ground connection
10	HALL_1	Hall sensor input 1 (analog and digital)
11	HALL_2	Hall sensor input 2 (analog and digital)
12	HALL_3	Hall sensor input 3 (analog and digital)

Notes

- Polarization hole on PCB indicates pin 1 and ensures correct cable position.
- See Feedback connections for further information about different feedbacks wiring.
- Neptune connectors include locking latches that provide audible click during mating and ensure assembly robustness

I/O Starter Kit and Cable Kit

Feedback connector pinout is shared with Jupiter, Pluto, Nix and Hydra servo drives, which allows using the IO starter kit and Pluto Cable Kit.

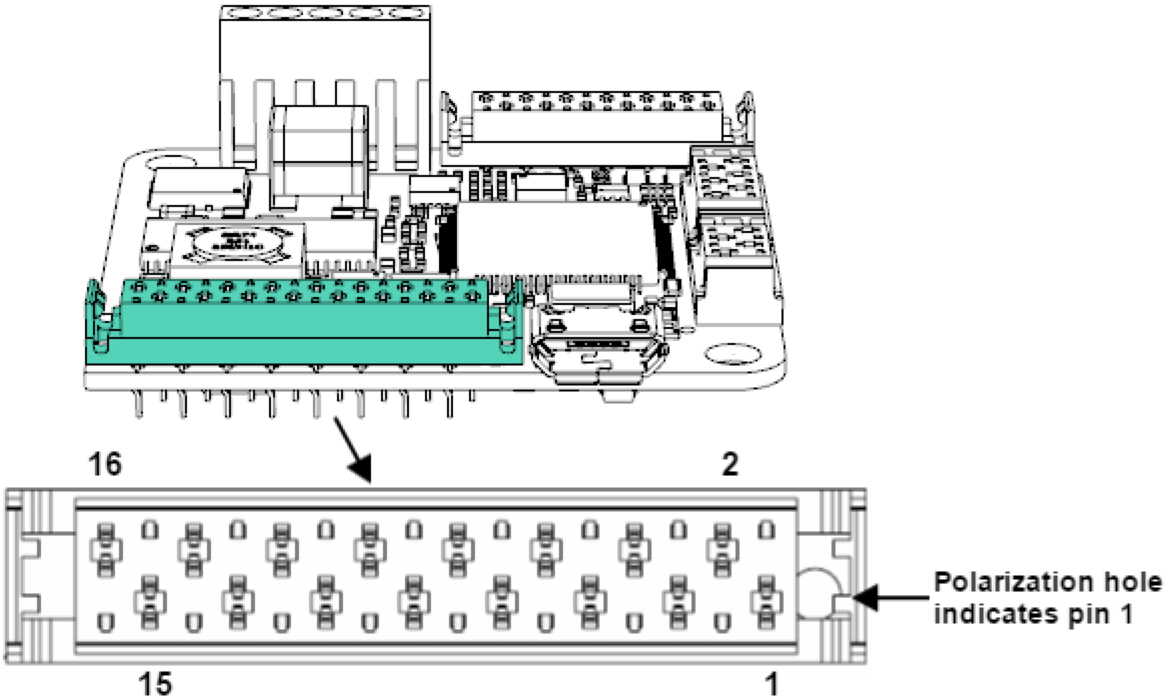
Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch 12 position
Part number	TE Conectivity 8-215083-2
Distributor codes	Farnell 149093 Digi-Key A99460CT-ND Mouser 571-8-215083-2
Cable	
Part number	3M 3302/16 300SF

Distributor codes	Farnell 1369751 Digi-Key MC16M-300-ND Mouser 517-C3302/16SF
Notes	
• For further information see Pluto cable Kit - Feedbacks.	

Multi-core crimped cable mating	
Description	TE Micro-Match housing connector 1.27 mm pitch 12 position
Part number	TE Connectivity 1-338095-2
Distributor codes	Digi-Key A99497-ND Mouser 571-1-338095-2
Cable	
Use 0.2 ~ 0.5 mm² (20 ~24 AWG) flexible wires.	

5.1.5 I/O connector

P3 Connector



16 pin 1.27 mm pitch [TE Micro-Match 1-338068-6]() connector.

Pin	Signal	Function
1	HS_GPI2+ / DIR+	High speed digital differential input 2+ Command source: Direction+ input
2	HS_GPI2- / DIR-	High speed digital differential input 2- Command source: Direction- input
3	GND	Ground
4	GPO2	Digital output 2 (open collector with weak pull-up to 5 V)
5	GPO1	Digital output 1 (open collector with weak pull-up to 5 V)
6	GND	Ground

7	HS_GPI1+ / PULSE+ / PWM+	High speed digital differential input 1+ Command source: Pulse+ input Feedback: PWM+ input
8	HS_GPI1- / PULSE- / PWM-	High speed digital differential input 1- Command source: Pulse- input Feedback: PWM- input
9	GND	Ground
10	AN_IN1	Single ended analog input 1
11	AN_IN2-	Differential analog inverting input 2 Single ended analog input 2 ground
12	AN_IN2+	Differential analog non inverting input 2 Single ended analog input 2
13	GND	Ground
14	GPI2	General purpose single ended digital input 2 (Could be torque off input on request)
15	GPI1	General purpose single ended digital input 1
16	+5V_OUT	+5V 200mA max output (shared with feedback connector)

Notes

- Polarization hole on PCB indicates pin 1 and ensures correct cable position.
- See I/O connections for further information about different I/O wiring.
- Neptune connectors include locking latches that provide audible click during mating and ensure assembly robustness

I/O Starter Kit and Cable Kit

I/O connector pinout is shared with Jupiter, Pluto, Nix and Hydra servo drives, which allows using the IO starter kit and Pluto Cable Kit.

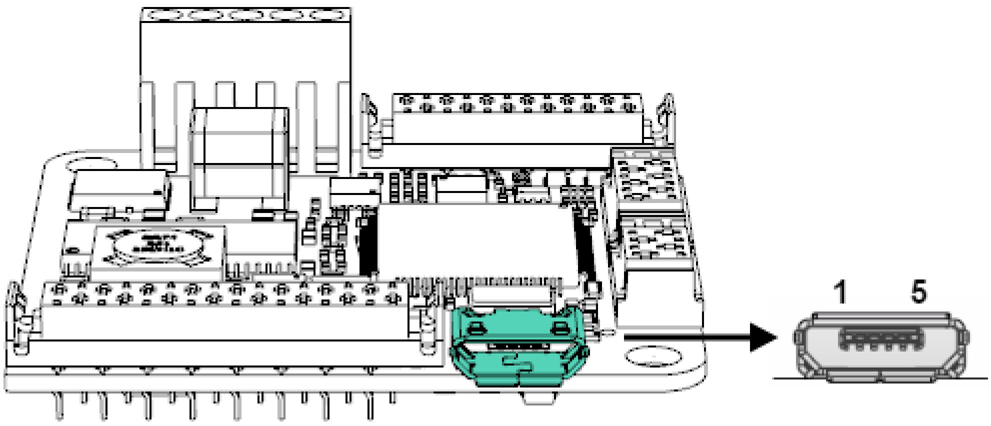
Ribbon cable mating

Description	TE Micro-Match Male-on-Wire 1.27 mm pitch 16 position
Part number	TE Connectivity 8-215083-6
Distributor codes	Farnell 149147 Digi-Key A99458CT-ND Mouser 571-8-215083-6
Cable	
Part number	3M 3302/16 300SF
Distributor codes	Farnell 1369751 Digi-Key MC16M-300-ND Mouser 517-C3302/16SF
Notes	
• For further information see Pluto cable Kit - General purpose I/O.	

Multi-core crimped cable mating	
Description	TE Micro-Match housing connector 1.27 mm pitch 16 position
Part number	TE Connectivity 1-338095-6
Distributor codes	Digi-Key A99495-ND Mouser 571-1-338095-6
Cable	
Use 0.2 ~ 0.5 mm^2 (20 ~24 AWG) flexible wires.	

5.1.6 USB connector

P4 Connector



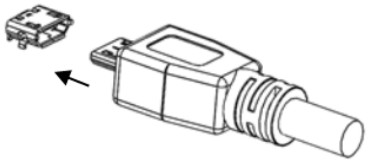
5 pin horizontal micro-USB connector Amphenol FCI 10118193

Pin	Signal	Function
1	USB_SUPPLY	USB +5 V supply input. Used to power logic circuits when no external power supply is available.
2	USB_D-	USB Data- line
3	USB_D+	USB Data+ line
4	NC	Not connected
5	GND	Ground
SHIELD	NC	Connector metallic shield, NOT CONNECTED.

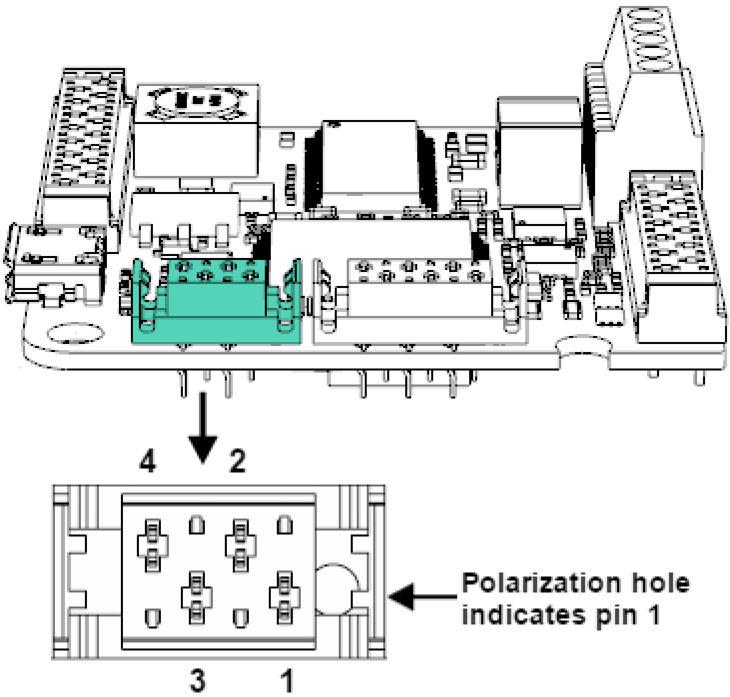
Notes

- Micro-USB connection allows easy access to the drive configuration using Motion Lab or downloading latest firmware revision.
- Shorter USB cables are preferred whenever possible for minimal EMI.
- Avoid applying excessive mechanical stress to the USB connector.
- Please see Communications page for further information

Mating	
Description	USB Shielded I/O Cable Assembly, USB A-to-Micro-USB B, 1.50m Length, Black, Lead-Free

Mating	
Image	
Part number	Molex 68784-0002
Distributor codes	Farnell 1617586 Digi-Key WM17146-ND Mouser 538-68784-0002

5.1.7 CAN connector

P5 Connector
 4 pin TE Micro-Match 338068-4 connector.

Pin	Signal	Function
1	CAN_GND	CAN ground (connected to circuit ground)
2	CAN_L	CAN bus line dominant low
3	CAN_H	CAN bus line dominant high
4	CAN_GND	CAN ground (connected to circuit ground)
Notes		
• Polarization hole on PCB indicates pin 1 and ensures correct mating connector position. • See Communications for further information about CAN wiring. • Neptune connectors include locking latches that provide audible click during mating and ensure assembly robustness		

Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch 4 position
Part number	TE Connectivity 215083-4
Distributor codes	Farnell 2399655 Digi-Key A107032TR-ND Mouser 571-215083-4
Cable	
Part number	3M HF365/04SF
Distributor codes	Farnell 2396432 Digi-Key MD04R-100-ND Mouser 517-HF365/04SF
Notes	

> **Wire impendance**
>
> Typical flat ribbon cables with 1.27 mm pitch spacing have 90 Ω to 150 Ω differential impedance. For best CAN bus performance at high baud rates, the ribbon cable impedance should be ~120 Ω.

Multi-core crimped cable mating	
Description	TE Micro-Match housing connector 1.27 mm pitch 4 position
Part number	TE Connectivity 338095-4
Distributor codes	Farnell 2420421 Mouser 571-338095-4
Cable	
Use 0.2 ~ 0.5 mm^2 (20 ~24 AWG) twisted pair with 120 Ω differential impedance.	

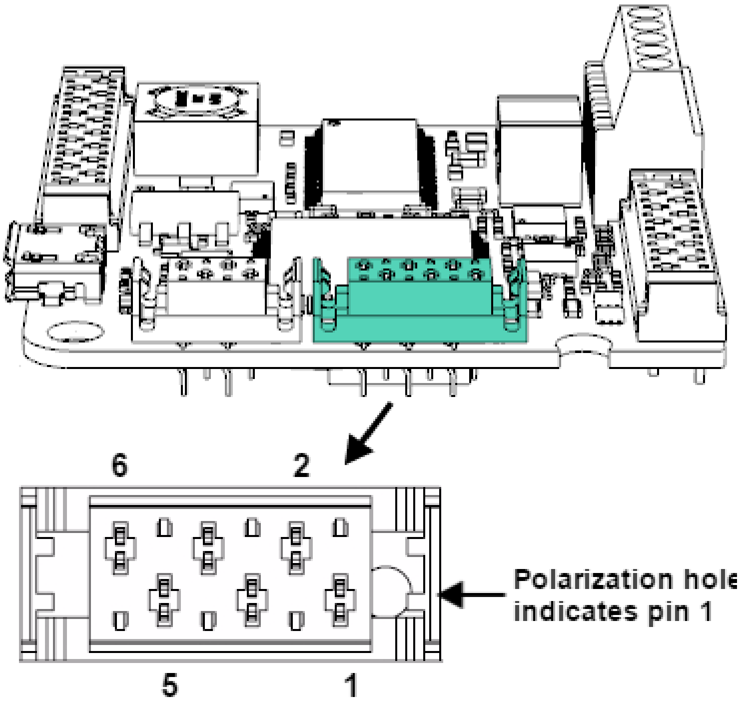
5.1.7.1 Cleverly wiring CAN buses from standard DB9 connectors

The Neptune CAN pinout allows an easy connection to the standard DB9 connector using a 4 way 1.27 pitch flat ribbon cable.
Use a DB9 to ribbon connector like: H7MXH-0906M-ND or AMPHENOL L117DEFRA09S-ND. Corresponding pinouts:

Neptune Micro-Match	DB9 standard to ribbon cable
1 (CAN_GND)	6 (CAN_GND)
2 (CAN_L)	2 (CAN_L)
3 (CAN_H)	7 (CAN_H)
4 (CAN_GND)	3 (CAN_GND)

5.1.8 RS232 interface connector

P6 Connector



6 pin TE Micro-Match 338068-6 connector.

Pin	Signal	Function
1	RETURN_TX	Internally connected to pin 6. Used only to simplify daisy chain wiring.
2	GND	Common (internally connected to drive GND)
3	RX	RS232 receive data (should be connected to master TX)
4	TX	RS232 transmit data (should be connected to master RX)
5	GND	Common (internally connected to drive GND)
6	RETURN_TX	Internally connected to pin 1. Used only to simplify daisy chain wiring.

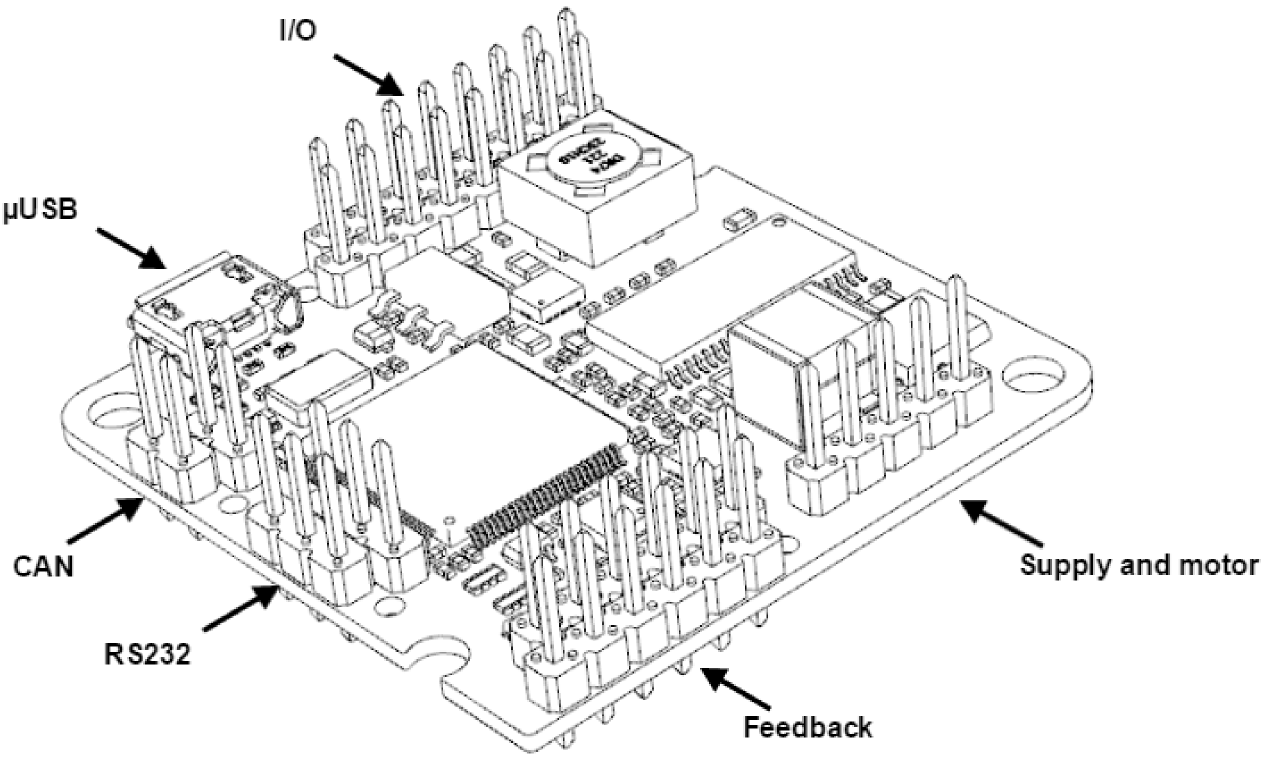
Notes

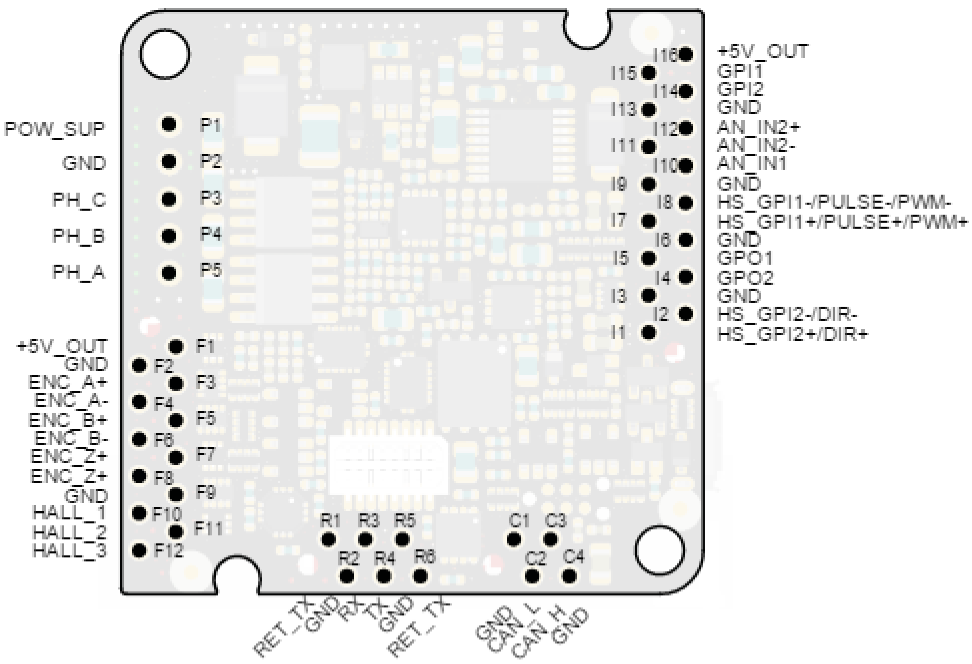
- Polarization hole on PCB indicates pin 1 and ensures correct mating connector position.
- See Communications for further information about RS232 wiring.
- Neptune connectors include locking latches that provide audible click during mating and ensure assembly robustness

Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch 6 position
Part number	TE Connectivity 215083-6
Distributor codes	Digi-Key A99463CT-ND Mouser 571-7-215083-6
Cable	
Part number	3M HF365/06SF
Distributor codes	Farnell 1859550 Digi-Key MD06R-100-ND Mouser 517-HF365/06SF

Multi-core crimped cable mating	
Description	TE Micro-Match housing connector 1.27 mm pitch 6 position
Part number	TE Connectivity 338095-6
Distributor codes	Digi-Key A99416-ND Mouser 571-338095-6
Cable	
Use 0.2 ~ 0.5 mm^2 (20 ~24 AWG) flexible cable.	

5.2 Connectors position and pinout of Neptune with gold plated pin headers (NEP-x/xx-y-P)





Bottom-side pinout

Note that the pinout diagram shows the board from the opposite side of the connectors (bottom side of Neptune).

Pin	Name	Description

P1	POW_SUP	Positive power supply input
P2	GND	Negative power supply input (Ground)
P3	PH_C	Motor phase C (Not connected in DC motors and voice coils)
P4	PH_B	Motor phase B (Negative for DC and voice coils)
P5	PH_A	Motor phase A (Positive for DC and voice coils)
I1	HS_GPI2+ / DIR+	High speed digital differential input 2+ Command source: Direction+ input
I2	HS_GPI2- / DIR-	High speed digital differential input 2- Command source: Direction- input
I3	GND	Ground
I4	GPO2	Digital output 2 (open collector with weak pull-up to 5 V)
I5	GPO1	Digital output 1 (open collector with weak pull-up to 5 V)
I6	GND	Ground
I7	HS_GPI1+ / PULSE+ / PWM+	High speed digital differential input 1+ Command source: Pulse+ input Feedbacks: PWM+ input
I8	HS_GPI1- / PULSE- / PWM-	High speed digital differential input 1- Command source: Pulse- input Feedbacks: PWM- input
I9	GND	Ground
I10	AN_IN1	Single ended analog input 1
I11	AN_IN2-	Differential analog inverting input 2 Single ended analog input 2 ground

I12	AN_IN2+	Differential analog non inverting input 2 Single ended analog input 2
I13	GND	Ground
I14	GPI2	General purpose single ended digital input 2 (Could be torque off input on request)
I15	GPI1	General purpose single ended digital input 2
I16	+5V_OUT	+5V 200mA max output (shared with feedback connector)

Pin	**Name**	**Description**
R1	RETURN_TX	Daisy chain TX return line, connected to pin 6
R2	GND	Common (internally connected to drive GND)
R3	RX	RS232 receive data (should be connected to master TX)
R4	TX	RS232 transmit data (should be connected to master RX)
R5	GND	Common (internally connected to drive GND)
R6	RETURN_TX	Daisy chain TX return line, connected to pin 1
C1	CAN_GND	CAN ground (connected to circuit ground)
C2	CAN_L	CAN bus line dominant low
C3	CAN_H	CAN bus line dominant high
C4	CAN_GND	CAN ground (connected to circuit ground)
F1	+5V_OUT	5 V @ 250mA supply for feedbacks

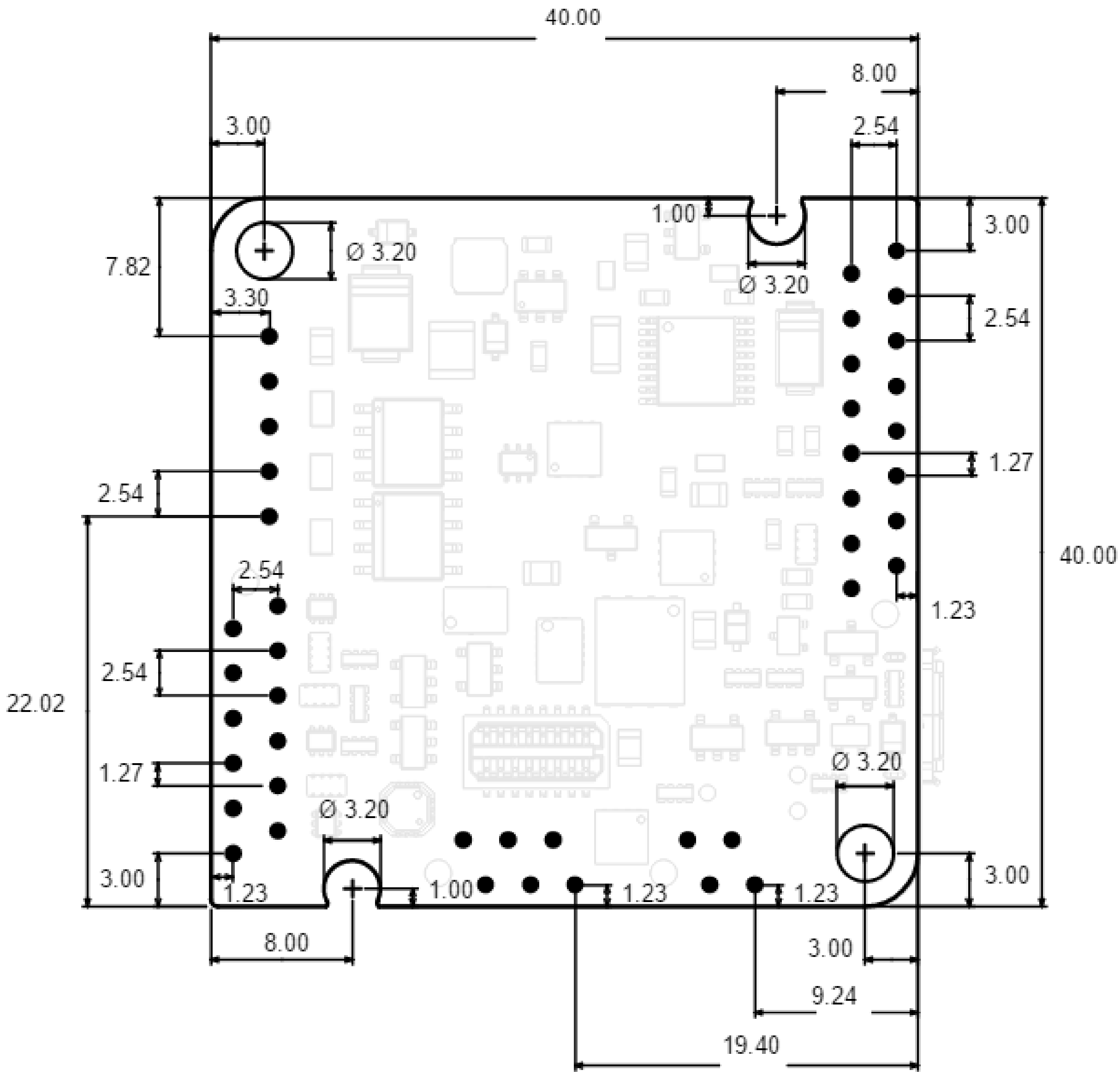
F2	GND	Ground connection
F3	ENC_A+	Single ended digital encoder: A input Differential digital encoder: A+ input
F4	ENC_A-	Differential Encoder: A- input
F5	ENC_B+	Single ended digital encoder: B input Differential digital encoder: B+ input
F6	ENC_B-	Differential Encoder: B- input
F7	ENC_Z+	Single ended digital encoder: Index input Differential digital encoder: Index+ input
F8	ENC_Z-	Differential Encoder: Index- input
F9	GND	Ground connection
F10	HALL_1	Hall sensor input 1 (analog and digital)
F11	HALL_2	Hall sensor input 1 (analog and digital)
F12	HALL_3	Hall sensor input 1 (analog and digital)

5.2.1 Integrating the Neptune with pin headers on a PCB

The Neptune pin header version is designed to be soldered or plugged on a PCB.

5.2.1.1 Dimensions

The picture below shows the Neptune dimensions and holes from the bottom point of view.



All dimensions are in mm

Footprint notes

- Pinout is shown from the bottom side because Neptune with pin headers is mounted upside down.
- 3.20 mm diameter holes are mechanical fixing holes
- Pin header pitch: 2.54 mm
- Recommended pin header trough hole pad diameter: 0.9 mm (varies depending on the chosen pin receptacle)
- Avoid placing high components under the board. Check mechanical interference with the Neptune (for more details see Dimensions).

Routing the PCB

- The **traces should always be as short as possible** to minimize potential EMI issues.
- Take due care with **signal returns** and GND routing, especially for high speed signals and analog inputs.
- **Do NOT use a general ground plane** as this could cause unwanted ground loops.
- The **width of the traces** should be according to the current carrying capacity. For motor and supply traces use generous thick traces.
- **Spacing of the traces** on external layers is crucial to guarantee safety. Recommended spacing for power and motor lines should exceed 0.4 mm (1.5 mm recommended).
- Keep power and signal traces separated.

5.2.1.2 Mating connectors

If instead of soldering, a pluggable PCB is needed, following mating connectors are suggested.

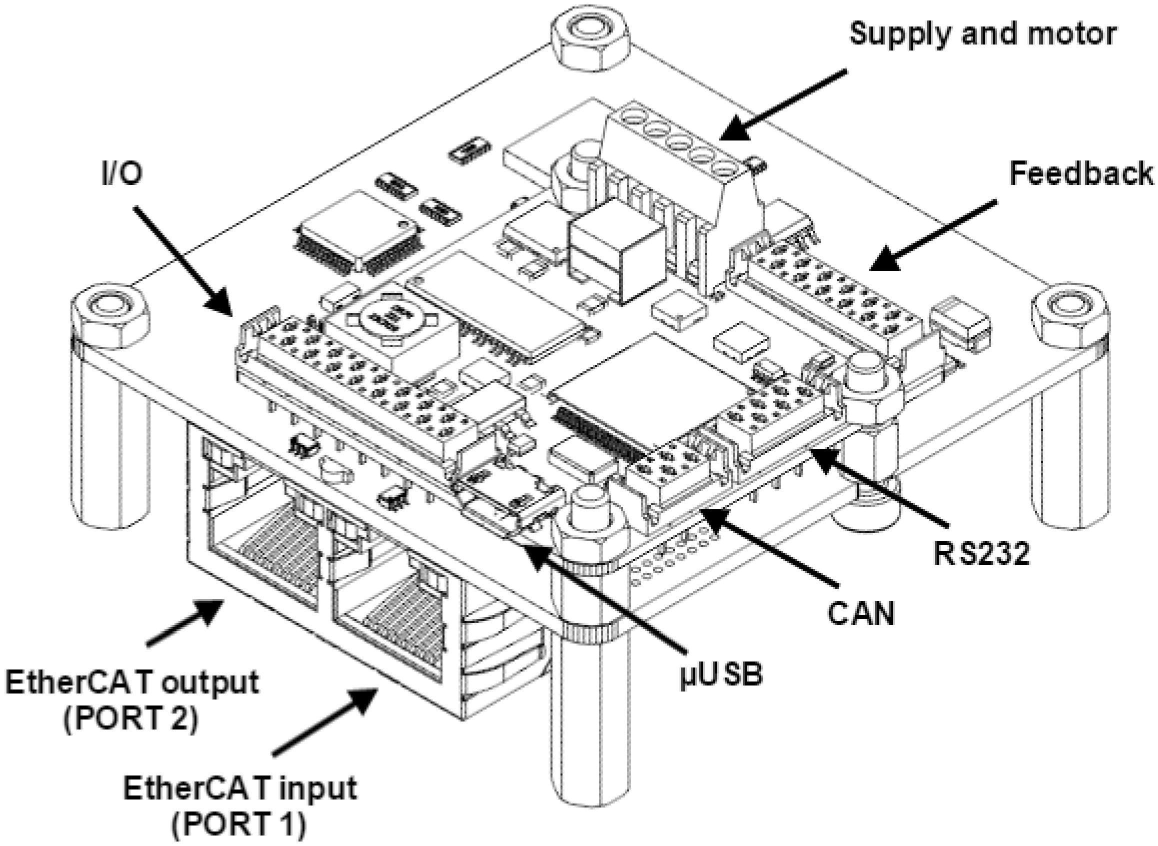
Connector	Description	Part number	Image	Distributor code	Quantity
Supply and motor	5-way pin receptacle 8.5 mm height 2.5 mm width Gold flash	Sullins PPTC051LFBN-RC		Digi-Key S7038-ND	1
Feedback	8-way pin receptacle 8.5 mm height 2.5 mm width Gold flash	Sullins PPPC081LFBN-RC		Digi-Key S7041-ND	2
I/O	6-way pin receptacle 8.5 mm height 2.5 mm width Gold flash	Sullins PPPC061LFBN-RC		Digi-Key S7039-ND	2

Connector	Description	Part number	Image	Distributor code	Quantity
CAN	2-way pin receptacle 8.5 mm height 2.5 mm width Gold flash	Sullins PPPC021LFBN-RC		Digi-Key S7035-ND	2
RS232	3-way pin receptacle 8.5 mm height 2.5 mm width Gold flash	Sullins PPPC031LFBN-RC		Digi-Key S7036-ND	2

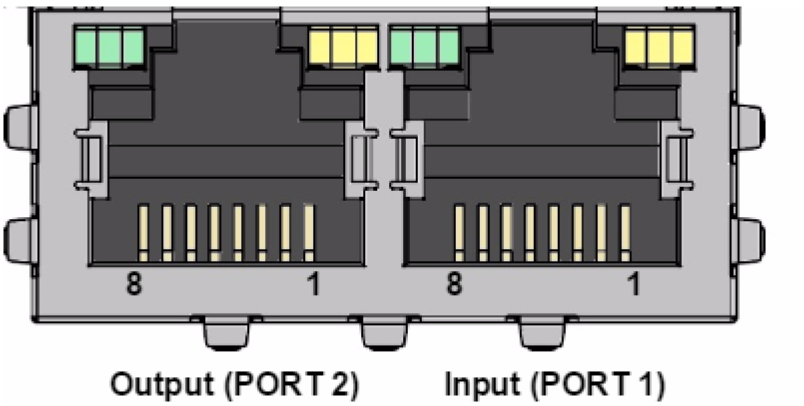
Gold-finish mating

To avoid connection reliability problems, connectors with gold finish are recommended

5.3 Connectors position and pinout of Neptune with EtherCAT (NEP-x/xx-E-z)



5.3.1 EtherCAT connectors

P7-P8 Connectors		
 Dual RJ45 connector Magjack Wurth 7499021125		
Pin	**Signal**	**Function**

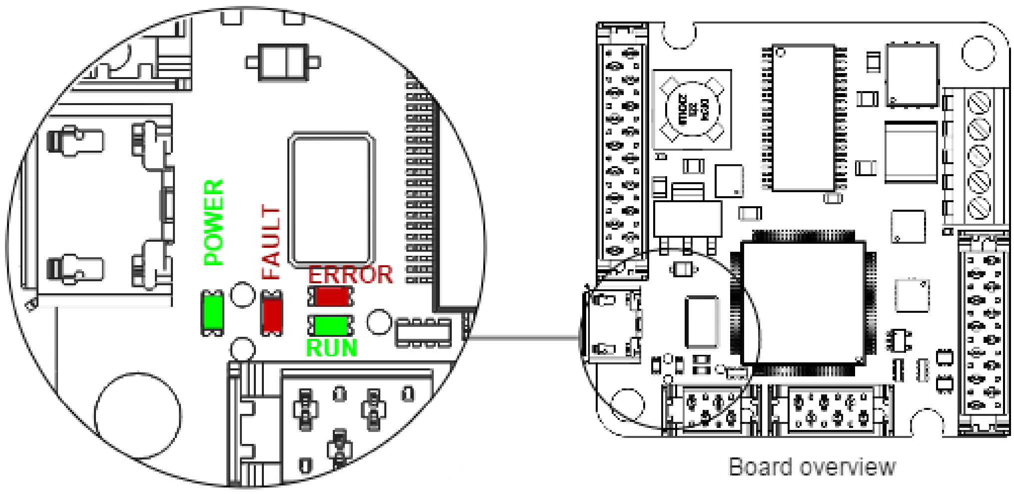
1	TX_D+	Transmit Data+ line
2	TX_D-	Transmit Data- line
3	RX_D+	Receive Data+ line
4	+2V5	2.5 V generated internally
5	+2V5	2.5 V generated internally
6	RX_D-	Receive Data- line
7	NC	Not connected
8	GND_CHASSIS	Connected to the connector chassis
Notes		
• Pinout is the same for Input (PORT 1) and output (PORT 2) connectors		

6 Signalling LEDs

Neptune Servo Drive provides information through 4 signalling LEDs:

- Supply and operation: 2 LEDs next to the CAN and USB connectors.
- CANopen communication: 2 LEDs next to the CAN and USB connectors.

Neptune with EtherCAT includes 3 more LEDs for the EtherCAT fieldbus status.



6.1 Power and operation signalling LEDs

Two LEDs situated next to the CAN and USB connectors indicate the supply and operation status. Next table shows the meaning of each LED:

LED	Colour	Meaning
POWER	**Green**	LED is on when internal power supply is working.
FAULT	**Red**	LED is on when a fault or error has occurred.

6.2 CAN signalling LEDs

Two LEDs besides the CAN and USB connectors provide information about the CANopen communication status, according to CiA 303-3 recommendations. The red LED is **ERROR LED** and green one is **RUN LED**.

ERROR LED indicates the status of the CAN physical layer and errors due to missed CAN messages (sync, guard or heartbeat). Next table the meaning of the ERROR LED states:

ERROR LED state*	**Concept**	**Description**
Off	No error	Device is in working condition.
Single flash	Warning limit reached	At least one of the error counters of the CAN controller has reached or exceeded the warning level (too many error frames).
Double flash	Error control event	A guard event (NMT-slave or NMT-master) or a heartbeat event (heartbeat consumer) has occurred.
Triple flash	Sync error	The sync message has not been received within the configured communication cycle period time out.
On	Bus off	The CAN controller is bus off.

RUN LED indicates the status of the CANopen network state machine. Next table shows the meaning of the RUN LED states:

RUN LED state*	**Concept**	**Description**
Off	Off	The device is switched off
Blinking	Pre-operational	The device is in state PREOPERATIONAL
Single flash	Stopped	The device is in state STOPPED
On	Operational	The device is in state OPERATIONAL

*See a detailed description of the states in the next table:

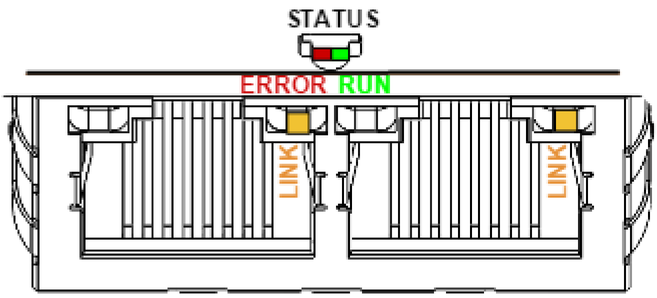
*** Possible LED States**	**Description**
ON	The LED is always on
OFF	The LED is always off

* Possible LED States	Description
Single flash	One short flash (~200 ms) followed by a long off phase (~1000 ms)
Double flash	Sequence of 2 short flashes (~200 ms), separated by an off phase (~200 ms). The sequence is finished by a long off phase (~1000 ms)
Triple flash	Sequence of 3 short flashes (~200 ms), separated by an off phase (~200 ms). The sequence is finished by a long off phase (~1000 ms)
Blinking	On and off with a frequency of ~2.5 Hz: ON for ~200 ms followed by off for ~200 ms.

Note that the specified timings can vary in up to ±20%.

6.3 EtherCAT signalling LEDs

The Neptune Servo Drive with EtherCAT fieldbus includes 3 more LEDs to indicate communication status according to EtherCAT specification.



The EtherCAT bicolor green/red LED indicates the EtherCAT state machine status. The green LED is the **RUN LED**, and the red LED is the **ERROR LED**. Next table shows their states meaning:

RUN LED state	EtherCAT slave status
Off	INIT
Blinking	PRE-OPERATIONAL
Single Flash	SAFE-OPERATIONAL
On	OPERATIONAL

ERROR LED state	EtherCAT slave status
Off	No error
Blinking	Invalid configuration
Single flash	Local error
Double flash	Watchdog timeout
On	Application controller failure

For high severity errors inside the Neptune Servo Drive, an special LED state has been developed:

Status	**Signalling**	**RUN LED state**	**ERROR LED state**
Internal error	Interleaved blink	Blinking (Initial status: OFF)	Blinking (Initial status: ON)

⚠ The frequency of the blinking is different than the used for communication and is product dependent.

The other two LEDs are situated in the EtherCAT connector. Each connector has two LEDs, but only the yellow LED is used. The **LINK LED** indicates the state of the EtherCAT physical link activity:

LINK LED	**Slave state**
Off	Port closed
Flickering	Port opened (activity on port)
On	Port opened (no activity on port)

7 Wiring and Connections

Proper wiring, and **especially grounding and shielding**, are essential for ensuring safe, immune and optimal servo performance of Neptune Servo Drive. Next pages show detailed connection recommendation as well as technical details of each interface.

- Protective earth
- Power supply
- Motor
- Feedback connections
- I/O connections
- Command sources
- Communications

7.1 Protective earth

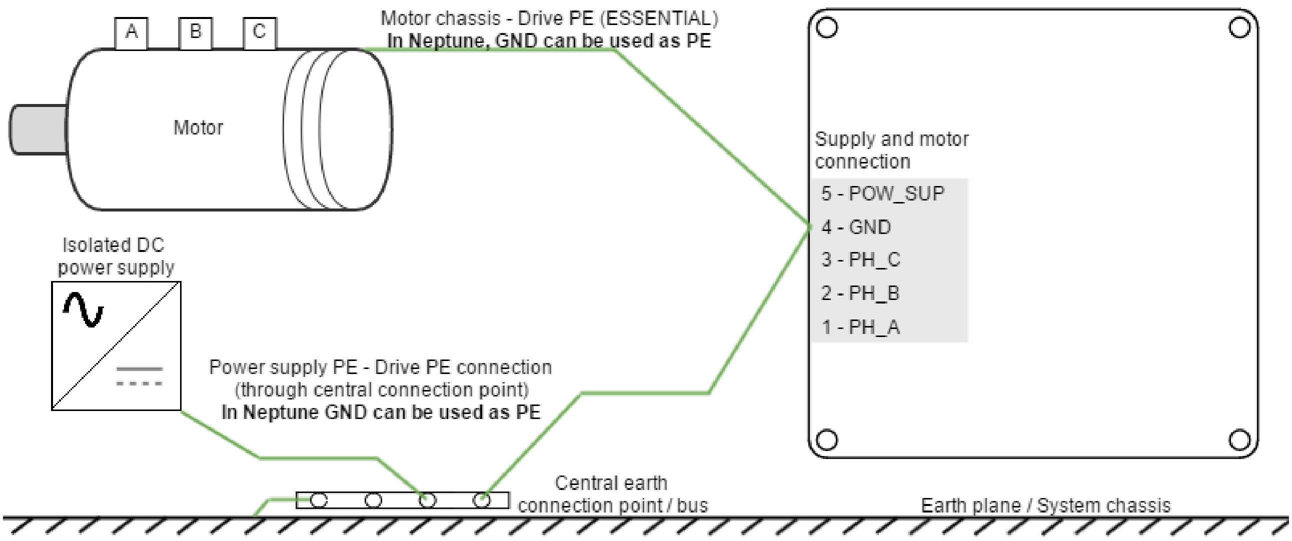
Connection of Neptune Servo Drive and motor housing to Protective Earth (PE) is required for **safety reasons.** Electrical faults can electrically charge the housing of the motor or cabinet, increasing the risk of electrical shocks. A proper connection to PE derives the charge to Earth, activating the installation safety systems (differential protections) and protecting the users.

Moreover, a proper connection to PE prevents many of the noise problems that occur operating a servo drive.

> **Reducing EMI susceptibility**
>
> **Connecting the drive to your system Earth and to the motor housing solves many noise and EMI problems.** This connection provides a low impedance preferential path for coupled common mode noises that otherwise would be coupled to sensitive electronics like the encoders. A good **grounding of the drive to the earth of the power supply** is also essential for a EMI reduction.

Neptune Servo drive does not have PE terminals. However, for reducing EMI problems **power GND can be used as PE.**

A diagram of the recommended Earth wiring is shown following.



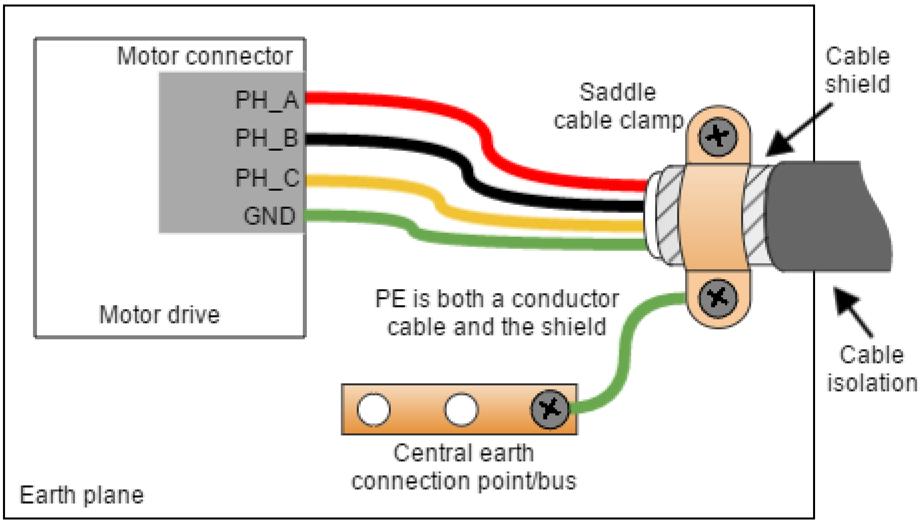
> **Earth plane reference**
>
> While some systems will not have a "real Earth" connection, use your **machine chassis**, the metallic structure of the device or a good grounding conductive plane as your reference earth.

Some considerations for a proper earth connection are detailed next:

- Switching noise can be coupled to the earth through the housing of the motor. This high-frequency noise creates common mode current loop between drive and motor. Although the motor housing is connected to earth through the system chassis, its electrical connection may have a relatively high impedance and present a big loop. For this reason is essential to reduce the common mode current return path impedance and its loop area.
    - For reducing the return path impedance, **motor frame should be directly wired** to drive PE terminals.
    - PE wiring should be as close as possible to power cables, reducing current loop.

- Power supply is another source of switching noise. The neutral of the grid transformer or the housing of our power supply may also be connected to earth. For reducing noise and EMI, similar considerations should be taken.
    - **Directly wire power supply PE to drive PE**.
    - PE wiring should be as close as possible to power supply cables.
- In order to avoid ground loops, it is a good practice to have a **central earth connection point (or bus)** for all the electronics of the same bench. If multiple drives are supplied from the same power supply or supply PE to drive PE connection is not practical (not enough connection terminals) connect all PE terminals in a central connection bus.
- Whenever possible, **mount the Ingenia drive on a metallic conductive surface** connected to earth. Use **good quality plated screws** that won't oxidize or lose conductivity during the expected lifetime. Note that the PE terminal is internally connected with the Neptune Servo Drive standoffs.
- For achieving low impedance connections, use wires that are **short, thick, multistrand cables** or preferably **conductive planes**. PE wire section should be, at least, the same as power supply cables. Always **minimize PE connection length**.

For an even better EMI immunity, **use shielded or armored cables** with isolating jacket, connecting the shield to PE with a cable clamp:



If a simplified wiring is required, the following shielding priority can be applied:

1. Shield the motor cables, which are the main high-frequency noise source.
2. Shield the feedback signals, which are sensitive signals usually coming from the motor housing.
3. Shield I/O signals and communication cables.

The **clamp has to be selected according to the shielded cable diameter**, **ensuring a good support and connection** between the cable shield and the clamp. Following examples are only suggested for conceptual purpose:

Description	**Image**	**Part number**
Cable Clamp, P-Type Silver Fastener 0.625" (15.88 mm)		Keystone Electronics 8107
Cable Clamp, P-Type Silver Fastener 0.187" (4.75 mm)		Keystone Electronics 8100
Cable Clamp, Saddle Type Stainless Steel 20 mm		RS Pro 471-1300

7.2 Power supply

The Neptune Servo Drive is supplied from the Supply and motor connector, using the same terminal for logic and power supply (9 V_{DC} to 48 V_{DC}). An internal DC/DC converter provides circuits with appropriate voltages as well as a regulated 5 V output voltage to supply feedback sensors and I/O.

The Neptune can be powered from USB for configuration purposes without the need of an external power supply. An internal switch automatically chooses the power source prioritizing the external supply. Please note that several functionalities will not be available when powered from USB.

USB Powered Neptune

When the Neptune is powered **from USB**, **only basic configuration and programming options are available**. The drive is not capable of driving a motor or sensing a feedback input due to USB power limitations.

Disconnection recommendations

There are no critical instructions for disconnecting the Neptune. Just some recommendations:

- The board could be hot during < 1 min after disconnection.
- Preferably do not disconnect the supply while having a motor in motion.
- If working with Motion Lab with USB connection, preferably disconnect the drive from the application before disconnecting. This prevents COM port corruption.

7.2.1 Power supply requirements

The choice of a power supply is mainly determined by voltage and current ratings of the power supply. Main requirements of the Neptune power supply are:

- The **voltage** should be the targeted for the motor. This means up to **48 V** for the **NEP-2/48**. Make sure that the voltage rating of the power supply does not exceed the voltage rating of the motor, otherwise it could be damaged.
- The **current** should be the one able to provide the phase peak current of the application. This means up to **5 A** for the **NEP-2/48-y-z.** Make sure that the current rating for the power supply is at least as high as the motor.
- The voltage and current range can be decreased due to the motor requirements.

Further information on how to dimension a power supply for the Ingenia drives can be found here**.**

Following are shown different power supply examples:

Manufacturer	Part Number	Rated Voltage (V)	Rated Current (A)	Image	Description
TDK Lambda	PFE300SA48/T	48	6.3		Switching closed frame power supply recommended for Neptune, 300 W

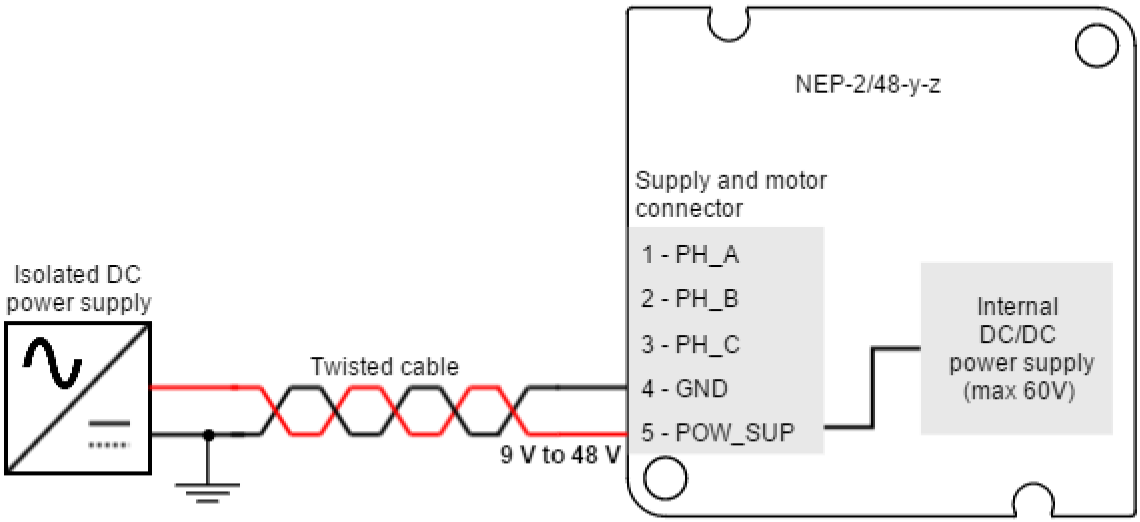
7.2.2 Power supply connection

Neptune logic and power supply are provided through the same terminal. All Neptune versions support an input voltage of +9 V to +48 V.

Twisted cables

Twisted power supply cables are preferred to reduce electromagnetic emissions and increase immunity.

The following picture show the Neptune supply wiring diagram.

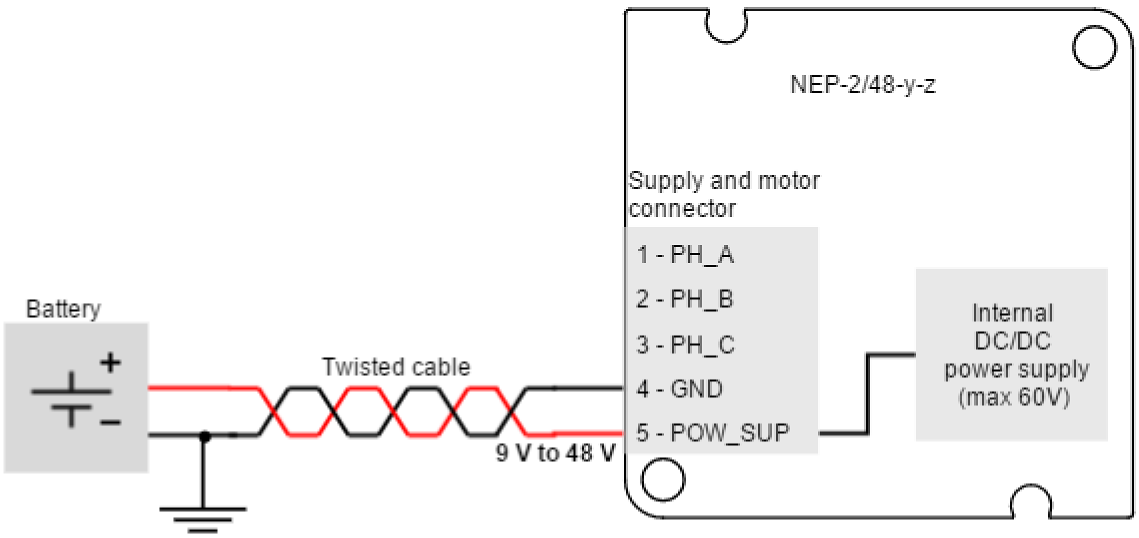


Isolated power supplies

For safety reasons, it is important to use **power supplies with full galvanic isolation**.

7.2.3 Battery supply connection

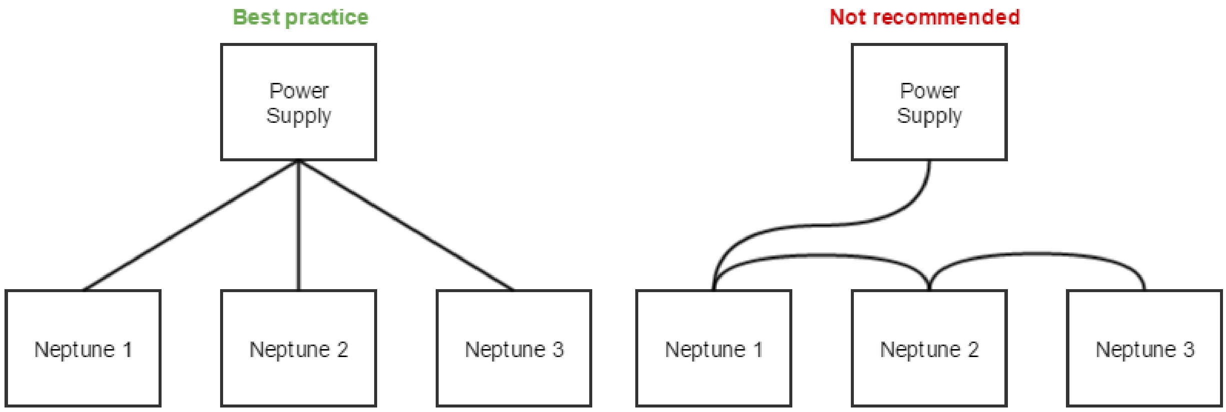
Next figure shows a simplified wiring diagram for the Neptune Servo Drive supplied from a battery.



> **Motor braking current**
>
> Motor braking can cause reverse current sense and charge the battery.
>
> Always ensure that the battery can accept this charge current which will be within the Neptune current ratings.

7.2.4 Connection of multiple drives with the same power supply

When **different servo drives are connected to the same power supply,** connect them in **star topology** for reducing cable impedance and common mode coupled noise. That is, connect each drive to the common supply using separate wires for positive and return.



7.2.5 Power supply wiring recommendations

7.2.5.1 Wire section

The minimum wire section is determined by the current consumption and the allowed voltage drop across the conductor. It is preferred to use **wide section stranded wires** to reduce impedance, power losses and ease the assembly. Insulator size should not exceed 2.54 mm (connector pitch). Following table indicates recommended section for the Neptune Servo Drive:

Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	0.25 mm^2 (23 AWG)	0.75 mm^2 (18 AWG)
Solid wire	0.25 mm^2 (23 AWG)	1 mm^2 (17 AWG)

7.2.5.2 Wire ferrules

For **low power applications**, it is recommended to use wire ferrules to prevent cable damage or wrong contacts. For **higher power applications, direct cable connection is recommended**, since it provides lower contact resistance. Due to the connector's size, the maximum allowed ferrule size is 0.25 mm^2. Ensure the insulator does not exceed 2.54 mm (connector pitch). Following table indicates recommended wire ferrules for the Neptune Servo Drive:

Manufacturer	Part number	Image	Description
Phoenix Contact	3203040		6 mm pin legth, 0.25 mm^2 (24 AWG)
Panduit Corp	FSD73-6-D		6 mm pin legth, 0.25 mm^2 (24 AWG)

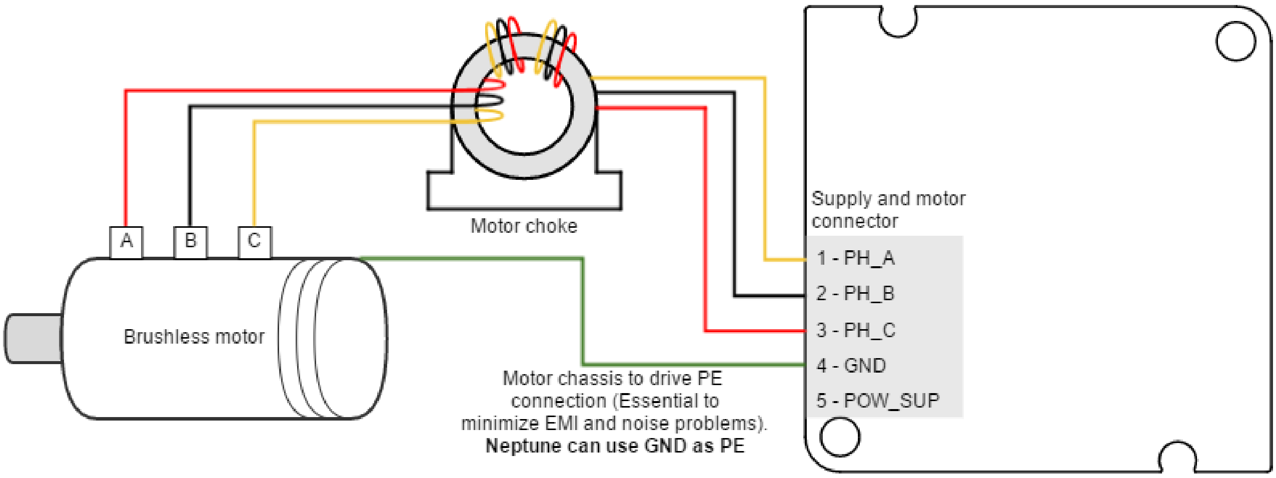
7.2.5.3 Wire length

- The distance between the Neptune Servo Drive and the power supply **should be minimized when possible**. Short cables are preferred since they reduce power losses as well as electromagnetic emissions and immunity.
- For best immunity use twisted and shielded 2-wire cables for the DC power supply. This becomes crucial in long cable applications.
- Avoid running supply wires in parallel with other wires for long distances, especially feedback and signal wires.

7.3 Motor

7.3.1 AC and DC brushless motors

Brushless motors should be connected to phase A, B and C terminals. Note that some manufacturers may use different phase name conventions (see Table below).



Phase name	Alphabetic	Numeric	UVW
PH_A	A	1	U
PH_B	B	2	V
PH_C	C	3	W

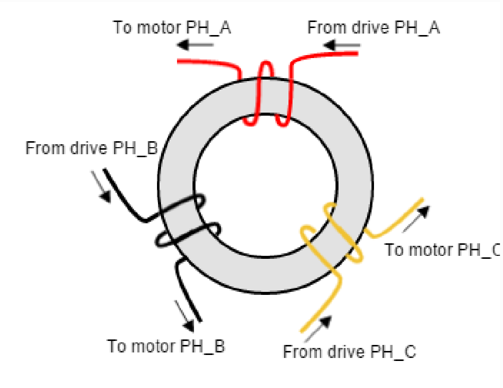
Common-mode choke

In order to minimize EMI that can affect sensitive signals, the use of a **motor choke** is recommended. The objective of the motor choke is to **block the common mode current** to the motor and cables. While using a separate choke for each phase could also work, the EMI reduction would be much lower than passing all the phases through the same choke.

Proper three-phase motor choke wiring

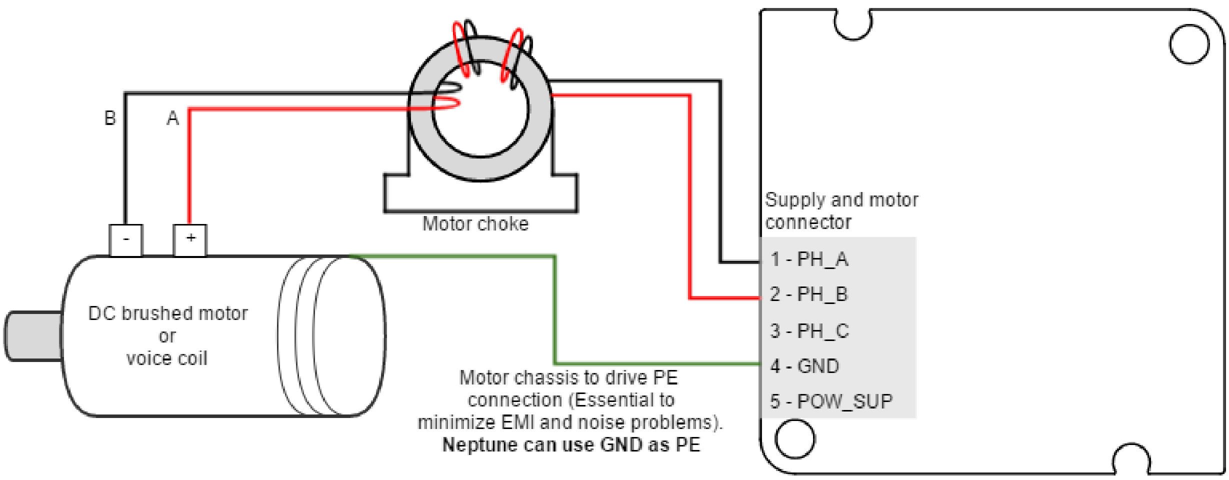
In order to minimize the capacitive coupling of the motor wires, and therefore cancelling the effect of the common mode rejection effect, the choke has to be properly wired.

- An excessive number of turns causes a high capacitive coupling. Only 2 or 3 turns per motor phase are recommended.
- For reducing the coupling between phases, space the phases 120º apart. **Start each phase wire in the same rotating direction**, wrapping all phases clockwise or anticlockwise. This will add the common mode flux and increase its impedance.



7.3.2 DC motors and voice coil actuators

DC motors and voice coil actuators are connected to phase A and phase B terminals. Phase C terminal is left unconnected.



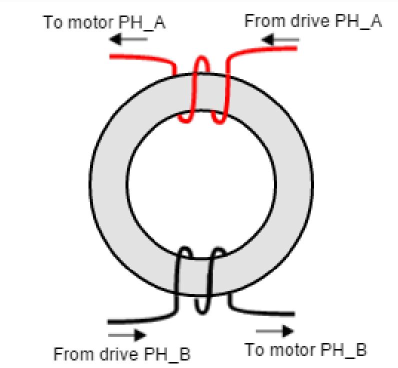
Common-mode choke

In order to minimize EMI that can affect sensitive signals, the use of a **motor choke** is recommended. The objective of the motor choke is to **block the common mode current** to the motor and cables. While using a separate choke for each phase could also work, the EMI reduction would be much lower than passing all the phases through the same choke.

Proper DC motor choke wiring

In order to minimize the capacitive coupling of the motor wires, and therefore cancelling the effect of the common mode rejection effect, the choke has to be properly wired.

- An excessive number of turns causes a high capacitive coupling. Only 2 or 3 turns per motor phase are recommended.
- For reducing the coupling between positive and negative, space them 180° apart. **Start positive and negative wire in the same rotating direction**, wrapping both phases clockwise or anticlockwise. This will add the common mode flux and increase its impedance.



7.3.3 Motor wiring recommendations

7.3.3.1 Wire section

The minimum wire section is determined by the motor current. It is preferred to use **wide section stranded wires** to reduce impedance, power losses and ease the assembly. Insulator size should not exceed 5 mm (connector pitch). Following table indicates recommended section for the Neptune Servo Drive:

Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	0.25 mm^2 (23 AWG)	0.75 mm^2 (18 AWG)
Solid wire	0.25 mm^2 (23 AWG)	1 mm^2 (17 AWG)

7.3.3.2 Wire ferrules

For **low power applications**, it is recommended to use wire ferrules to prevent cable damage or wrong contacts. For **higher power applications, direct cable connection is recommended**, since it provides lower contact resistance. Due to the connector's size, the maximum allowed ferrule size is 0.25 mm^2. Ensure the insulator does not exceed 2.54 mm (connector pitch). Following table indicates recommended wire ferrules for the Neptune Servo Drive:

Manufacturer	Part number	Image	Description
Phoenix Contact	3203040		6 mm pin legth, 0.25 mm^2 (24 AWG)

Manufacturer	Part number	Image	Description
Panduit Corp	FSD73-6-D		6 mm pin legth, 0.25 mm^2 (24 AWG)

7.3.3.3 Motor choke

Neptune Servo Drive has an onboard ferrite bead in each phase output to minimize its electromagnetic emissions (Z = 100 Ω @ 100 MHz). However, in applications where electromagnetic compatibility is a concern or that must comply with the EMC standards, the use of an external common mode choke is necessary. Some choke wiring recommendations are:

- Place the choke as close to the drive as possible.
- Make sure the chosen choke **does not saturate at the maximum operating phase current**. If this happens, the choke temperature would increase rapidly.
- **Only 2 or 3 turns of the motor cables** to the choke are recommended for best performance. Doing more than 3 turns reduces choke effectiveness, as capacitive coupling between wires would bypass the choke effect.
- **PE conductor should NOT** pass through the choke.
- Avoid contact of the toroid core with a grounding point.

Next table shows ferrites that fits the Neptune Servo Drive specifications.

Type	Manufacturer	Reference
Ferrite cable core	Laird Technology	LFB159079-000
Ferrite cable core	Laird Technology	LFB174095-000
Ferrite cable core	Laird Technology	LFB187102-000

7.3.3.4 Wire length

- The distance between the Neptune Servo Drive and the motor **should be minimized when possible**. Short cables are preferred since they reduce power losses as well as electromagnetic emissions and immunity.
- Avoid running motor wires in parallel with other wires for long distances, especially feedback and signal wires.
- The parasitic capacitance between motor wires should not exceed 10 nF. If very long cables (> 100 meters) are used, this value may be higher. In this case, add series inductors between the Neptune outputs and the cable. The inductors must be magnetically shielded, and must be rated for the motor surge current. Typical values are around 100 µH.

7.4 Feedback connections

The Neptune Servo Drive has a feedback connector dedicated to the following feedback options:

- Digital Halls
- Analog Halls
- Quad. Incremental encoder

Additional feedback connections can be found on I/O connector:

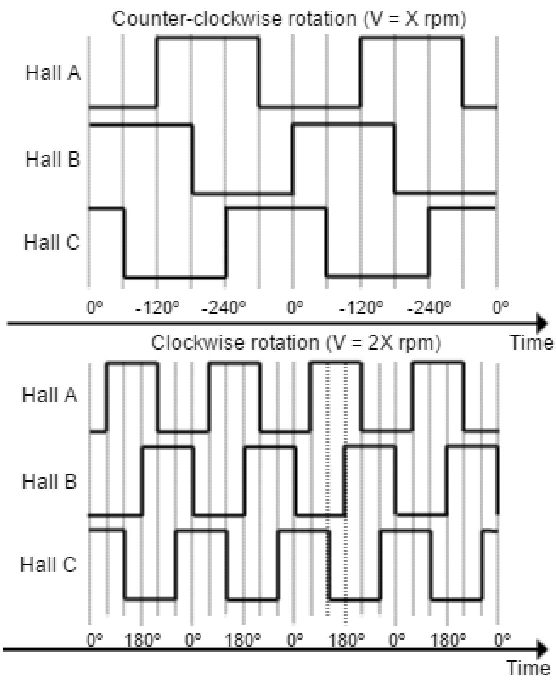
- PWM encoder
- Analog input for potentiometer
- Analog input for DC tachometer

Neptune also provides a 5V, 200 mA outputs for feedbacks supply. This output is overload and short circuit protected.

7.4.1 Digital Halls interface

The Hall sensors are Hall effect devices that are built into the motor to detect the position of the rotor magnetic field. Usually, motors include 3 hall sensors, spaced 120° apart. Using these 3 signals, the drive is capable to detect the position, direction and velocity of the rotor. Next figures show examples of digital halls signals.

Digital halls signals example



Digital halls can be used for commutation, position and velocity control. Resolution using these sensors is much lower than using encoders. **Neptune can use single ended Hall sensors to drive the motor with trapezoidal commutation, but not with sinusoidal commutation.**

This interface accepts 0-5 V level input signals. Inputs are pulled up to 5 V, so industry standard open collector and logic output hall effect sensors can be connected. Next table summarizes digital halls inputs main features:

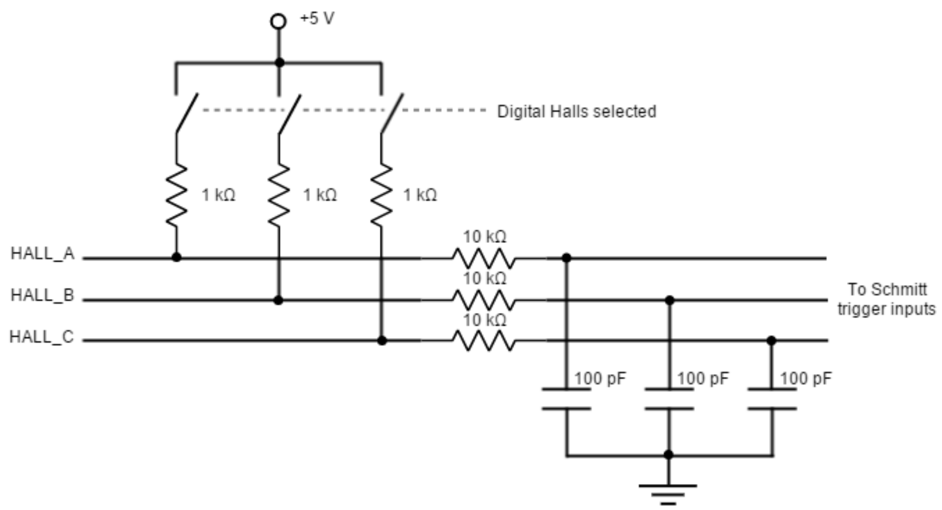
Specification	Value
Type of inputs	Non-isolated Single ended with pull-up and low pass filter ESD protected
Number of inputs	3
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact) IEC 61000-4-4 (EFT) 40 A (5/50 ns)
Voltage range	0 ~ 5 V
Maximum voltage range	-0.3 ~ 5.3 V
Maximum recommended working frequency	1 kHz
1st order filter cutting frequency (-3dB)	160 kHz
Sampling frequency	10 ksps
Type of sensors	Open collector Logic output Push-pull output
Pull-up resistor value	1 kΩ (The pull-up is activated only when the drive is configured to use digital hall sensors)

Digital and analog Halls

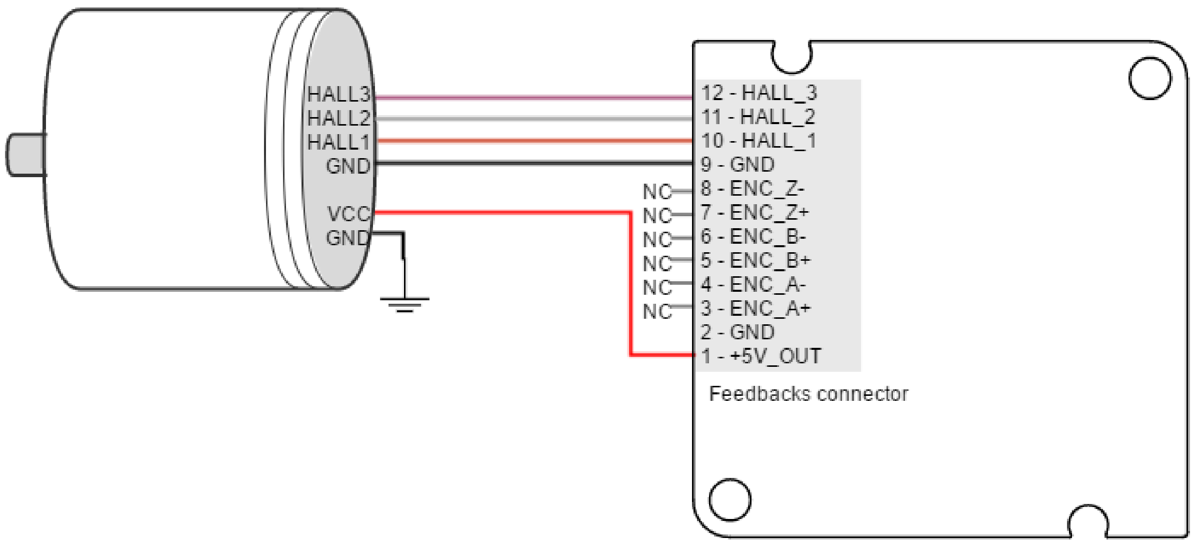
Digital halls input pins are shared with Analog Halls interface pins.

The 1 kΩ pull-up resistors are disconnected when Analog-halls input is selected to prevent analog data corruption.

Next figure shows the circuit model of the digital Halls inputs.



Next figure illustrates how to connect the digital halls to the Neptune Servo Drive. Refer to Feedback wiring recommendations for more information about connections and wires.



Velocity control with Halls

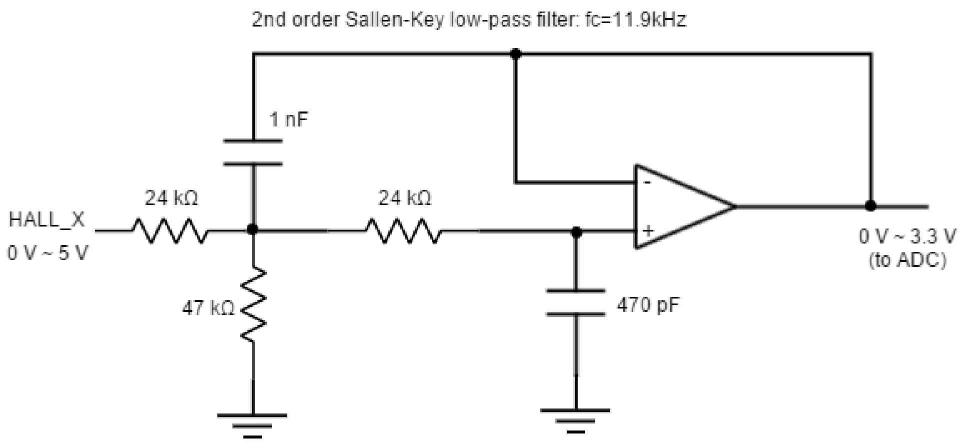
Due to inherent low resolution of motor mounted Hall sensors, they are not recommended for velocity feedback in low speed applications.

7.4.2 Analog Halls interface

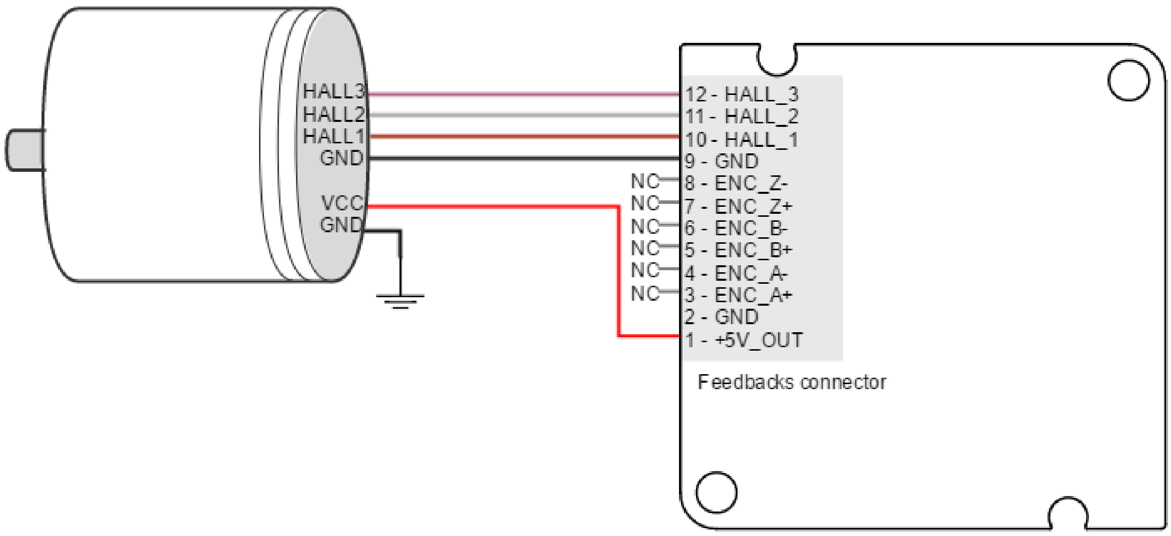
The Neptune Servo Drive can operate with analog Hall sensors (also known as linear halls) as feedback option. Signals provided by these sensors are typically 5 V peak-to-peak sinusoidal signals, with 2.5 V offset and a phase shift of 120 degrees. These sensors can be used for a fine positioning of the rotor. Neptune analog halls inputs main features are shown in next table:

Specification	**Value**
Type of inputs	Non-isolated Single ended analog filtered ESD protected
Number of inputs	3
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact) IEC 61000-4-4 (EFT) 40 A (5/50 ns)
Maximum recommended working frequency	1 kHz
2nd order filter cutting frequency	11.9 kHz
Sampling frequency	10 ksps
Voltage range	0 ~ 5 V (10 bits)
Maximum voltage range	-0.3 ~ 5.3 V
Input impedance	> 24 kΩ

Next figure illustrates the circuit model for one of the linear Halls inputs. An active Sallen-Key low pass filter provides immunity to motor and feedback noise. Note that analog halls pins are shared with Digital Halls interface, to avoid any signal distortion, when analog halls interface is selected, the 1 kΩ pull-up is disconnected automatically. .



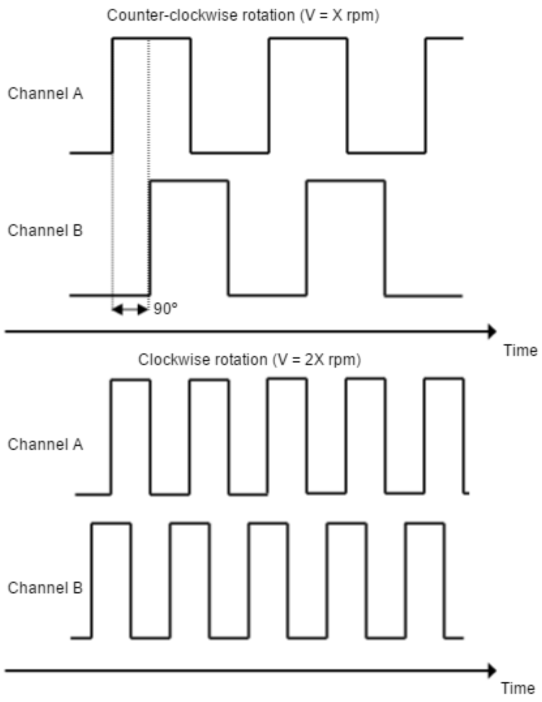
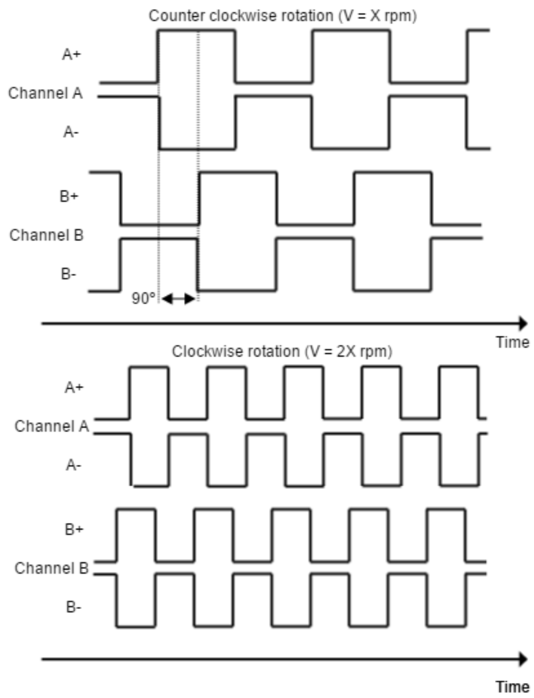
Next figure shows how to connect the linear Halls to the Neptune Servo Drive. Refer to Feedback wiring recommendations for more information about connections and wires.



7.4.3 Digital Incremental Encoder

Neptune can use single ended or differential digital incremental encoder inputs (also known as quadrature incremental encoders) for velocity and/or position control, as well as commutation sensor. The encoder provides incremental position feedback that can be extrapolated into precise velocity or position information. Using high resolution encoders allows Neptune Servo Drive to use sinusoidal commutation.

Channel A and channel B signals should have a phase shift of 90 degrees, indicating the rotation direction. Based on the pulses frequency, the drive can calculate the motor velocity and position.

Example of single ended digital encoder inputs	Example of digital differential encoder signals
	

High precision applications

High resolution motor mounted encoders allows excellent velocity and position control at all speeds. Encoder feedback should be used for applications requiring precise and accurate velocity and position control. Digital encoders are especially useful in applications where low-speed smoothness is the objective.

The Neptune Servo Drive has one differential digital encoder interface, with optional index signal input. Index signal (Z) is a single pulse per revolution signal that can be used to know absolute positions. Next table illustrates digital encoder inputs main features.

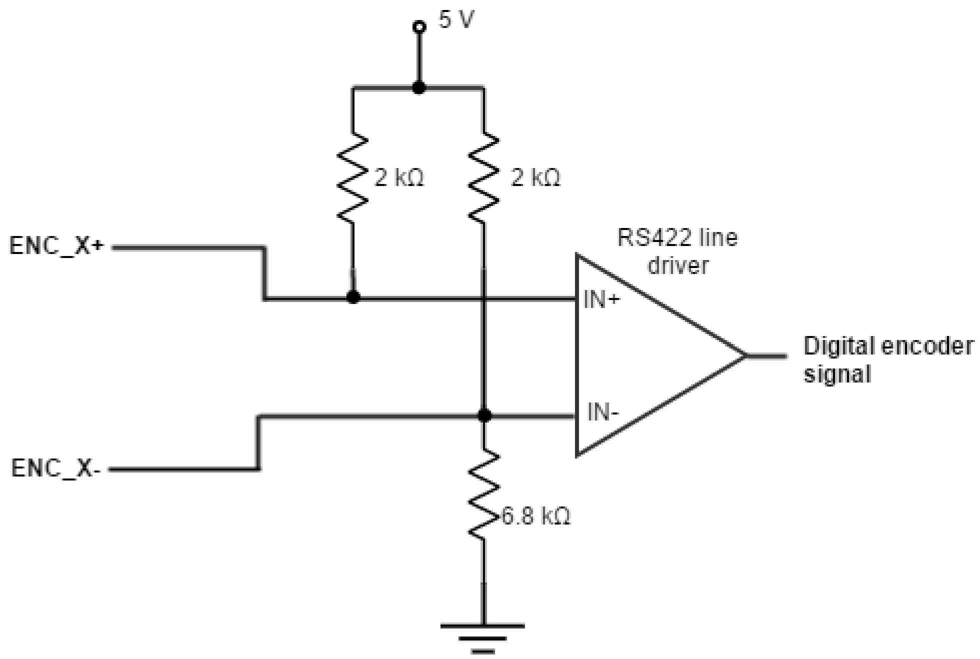
Specification	Value
Type of inputs	Non-isolated Differential or single ended ESD protected
Number of inputs	3 (A, B and Index)
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact) IEC 61000-4-4 (EFT) 40 A (5/50 ns)

Specification	**Value**
Nominal voltage range	0 ~ 5 V
Maximum voltage range	-0.3 ~ 5.3 V
Maximum recommended working frequency	10 MHz (differential)
Maximum readable pulse frequency	30 MHz
Bias resistors	ENC_x+ (positive input) 2 kΩ to 5 V ENC_x- (negative input) 1.5 kΩ to 4 V (equivalent)

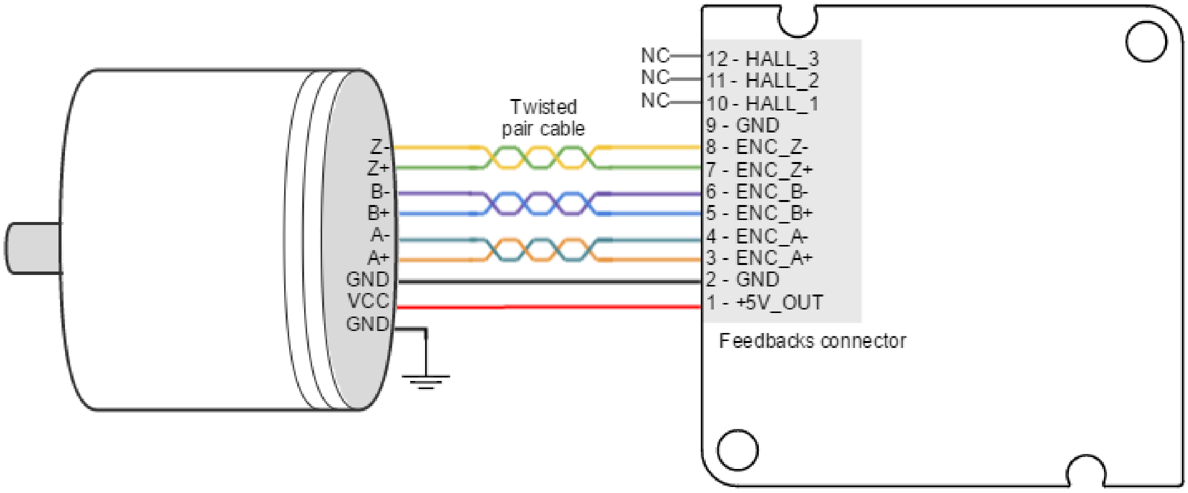
For encoder signal reception, an RS-422 differential line receiver is used. The high signals (ENC_A+, ENC_B+ and ENC_Z+) are pulled up to +5 V, and the low signals (ENC_A-, ENC_B- and ENC_Z-) are biased to 4 V (approx). This arrangement let the user to connect either differential output encoders or single ended encoders (both open collector and totem pole).

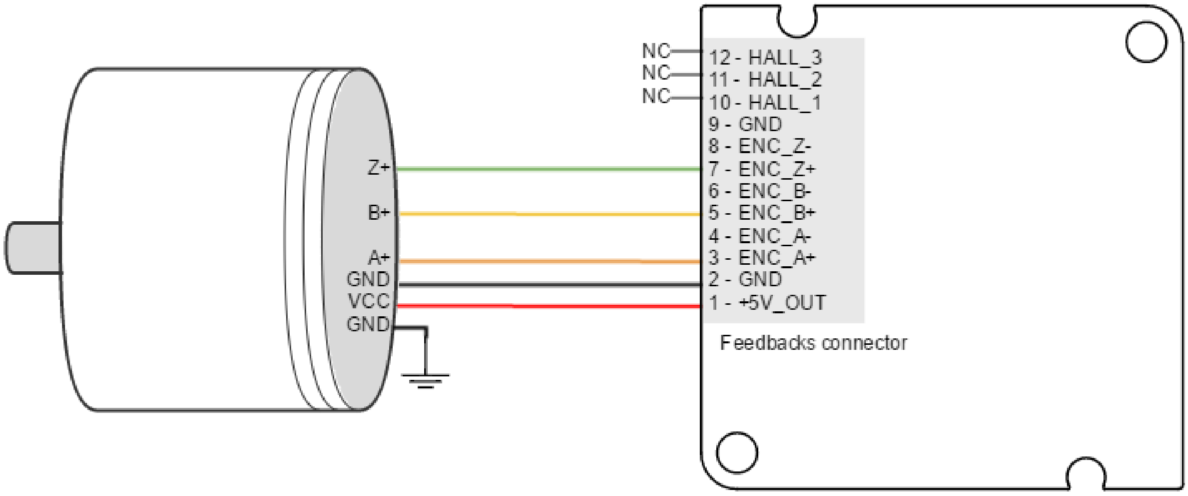
The encoder interface also accepts an RS-422 differential quadrature line driver signal in the range of 0 V to 5 V, up to 10 MHz. When single ended encoder is connected, only high signals (ENC_A+, ENC_B+ and ENC_Z+) must be used.

Next figure shows the circuit model of the digital encoder inputs.



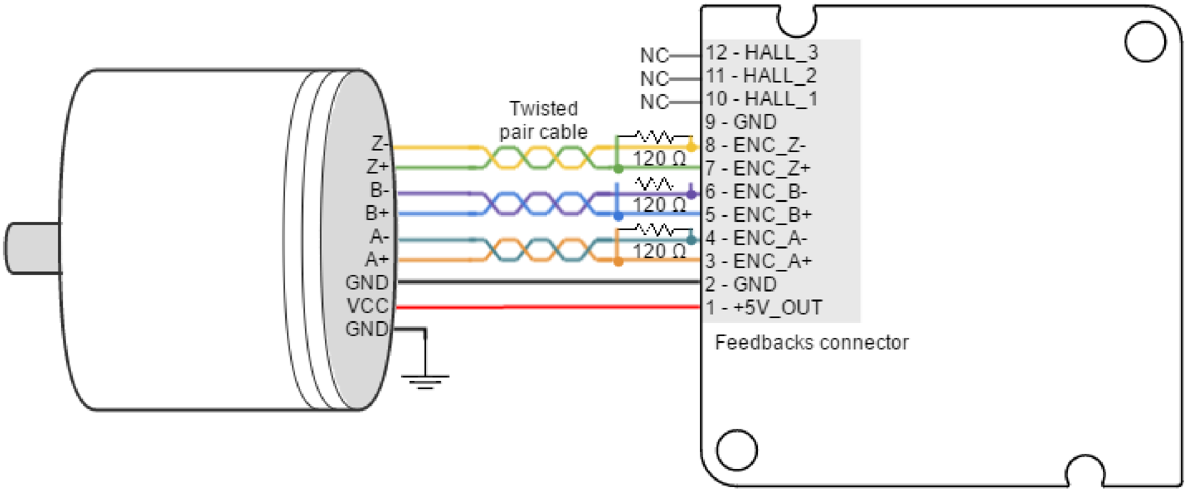
Next figures illustrate how to connect a differential and a single ended encoder to the Neptune Servo Drive. Refer to F eedback wiring recommendations for more information about connections and wires.



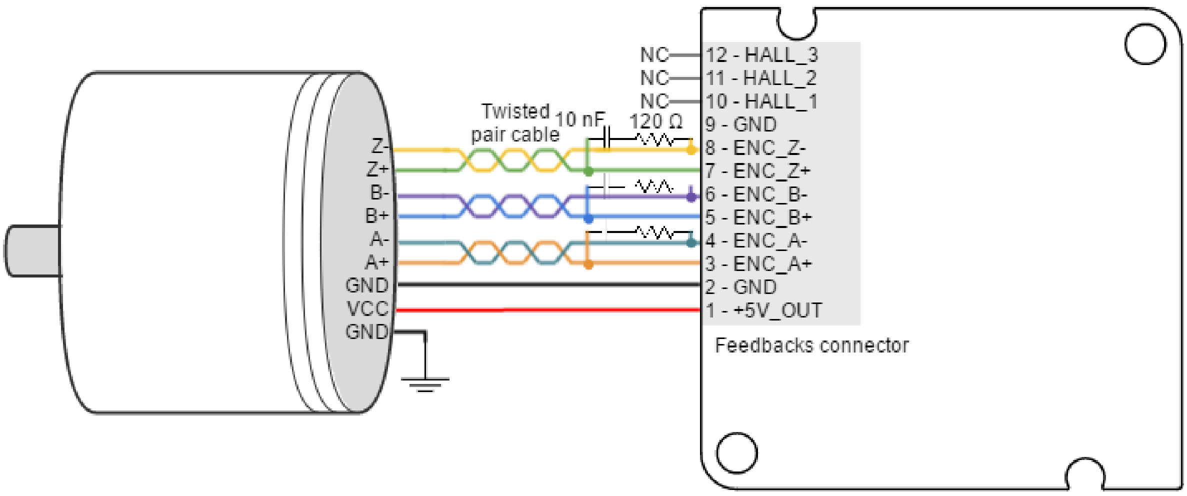


7.4.3.1 Termination resistors

The Neptune does not have termination resistors on board. In a noisy environment it is recommended to add 120Ω termination resistors between the positive and the negative lines of the differential signals of the encoder. Next figure shows how connect the termination resistors:



To minimize the power consumption, an AC termination topology can be used, which consist on connecting a 10 nF capacitor in series with the 120Ω termination resistors:



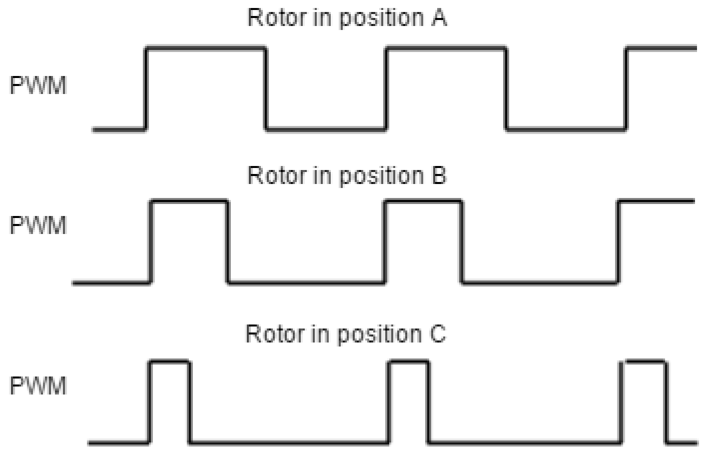
Suggested part numbers:

Manufacturer	PN	Description
Xicon	271-120-RC	Resistor 120Ω, 250 mW, 1%
Murata	RDER71E104K0P1H03B	Capacitor 0.1 µF, ceramic, X7R, 25 V

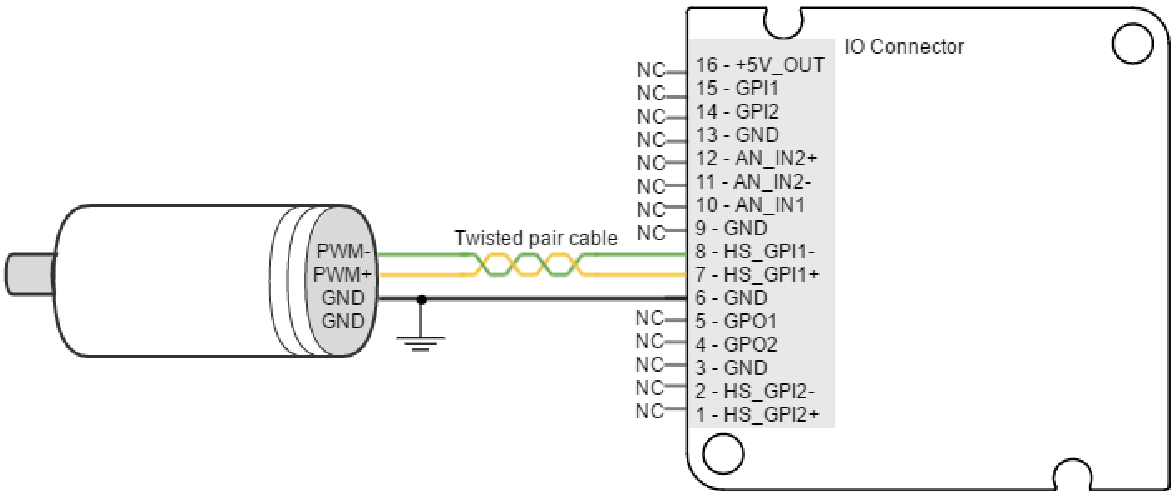
7.4.4 Digital input feedback - PWM encoder

Neptune Servo Drive can also use a PWM encoder connected through the I/O connector as a feedback element. A PWM encoder provides a Pulse Width Modulated (PWM) signal with a duty cycle proportional to the angle (position) of the rotor. This feedback can be interfaced through the high-speed digital input 1 (**HS_GPI1**). Both differential and single-ended PWM encoders can be used. Further specifications about the PWM input can be found in I/O connection section.

Next figure illustrates PWM feedback input for different rotor positions:

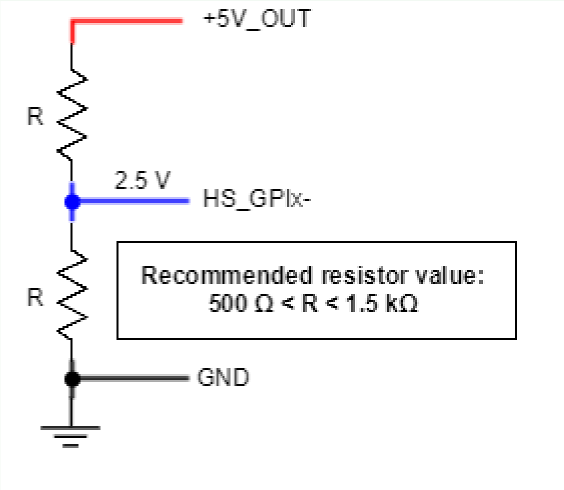


Next figure illustrates how to connect a differential PWM encoder to the Neptune Servo Drive:



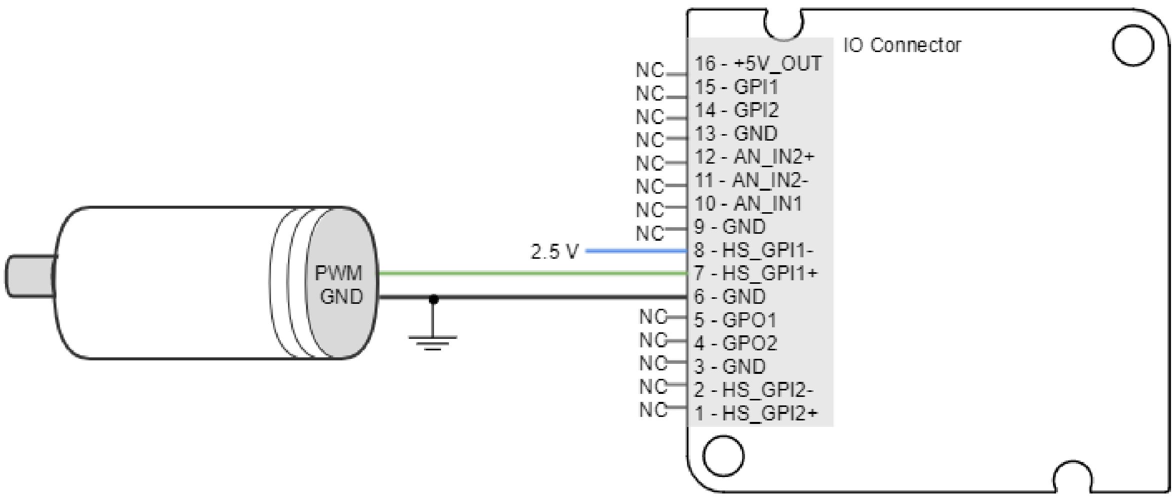
Single ended operation

In order to use the high-speed digital input in **single ended mode**, **connect the negative terminal (HS_GPIx-) to 2.5 V**. This voltage can be achieved with a voltage divider from +5V_OUT.



For a 24 V input, the negative terminal **(HS_GPIx-)** can be connected to 5 V (+5V_OUT).

Next figure illustrates how to connect a single ended PWM encoder to the Neptune Servo Drive:



Refer to Feedback wiring recommendations for more information about connections and wires. Refer to High-speed (HS) digital inputs interface for more information about High Speed digital inputs.

7.4.5 Analog input feedback

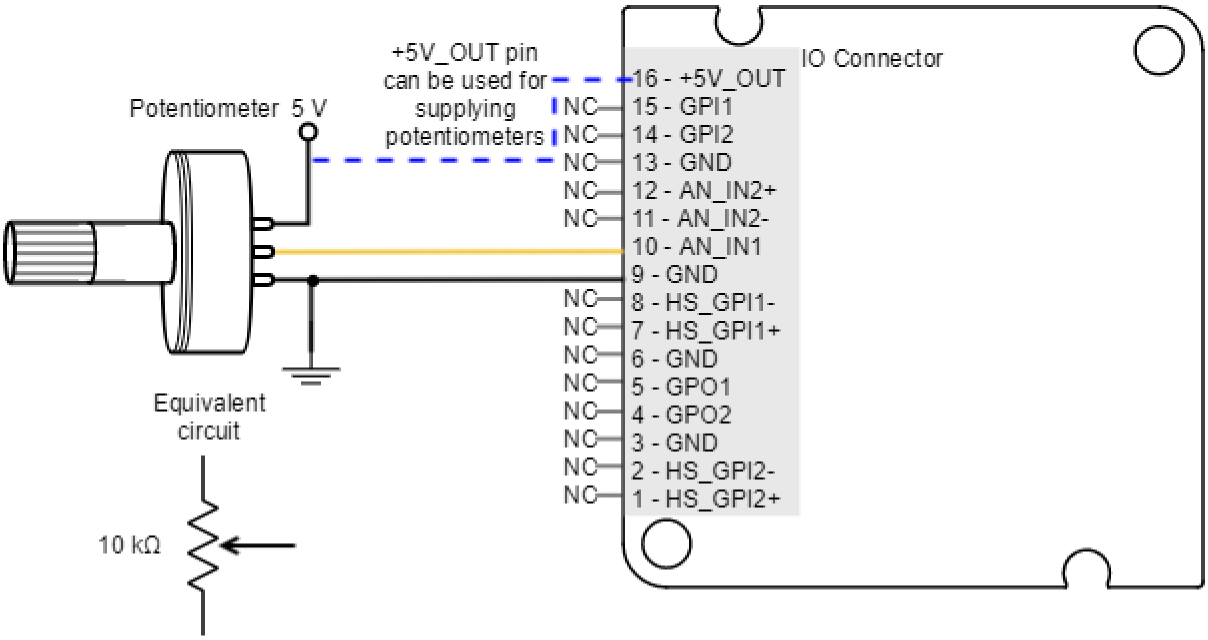
Neptune Servo Drive can also use analog feedback systems connected through the I/O connector. From the voltage level of one analog input, the position or velocity of the rotor can be calculated. The Neptune have 2 analog inputs that can be used for feedback input, each one with a different input range. The input used as feedback can be selected by software. Further specifications about the analog inputs input can be found in I/O connection section.

Refer to Feedback wiring recommendations for more information about connections and wires.

7.4.5.1 Potentiometer

A typical analog sensor used for position feedback is a potentiometer. This sensor provides a voltage proportional to the rotor position.

The following picture shows how to connect a potentiometer as a position sensor using analog input 1:



Recommended potentiometer resistance

Potentiometers with high values of resistance (> 10 kΩ) can result in non linear behavior due to its the drive parallel input resistors. High resistance values also reduce the signal to noise ratio, making it easier to have disturbances and reducing the quality of the measure.

However, a very small value of resistance may also consume too much power and cause self heating (which causes additional variations on resistance).

Therefore, **use the smallest value of resistance** that:

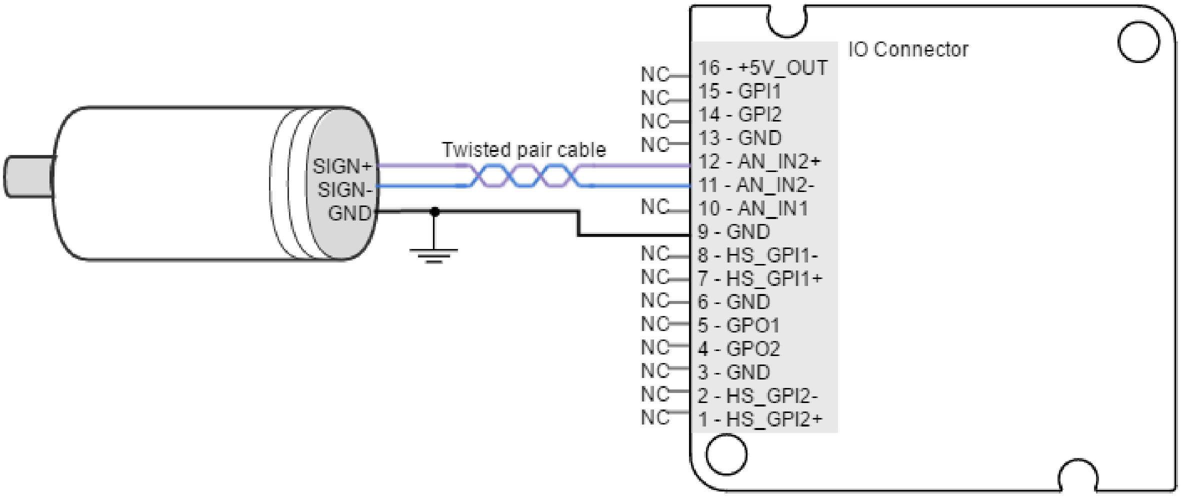
- Does not exceed 1/2 of the potentiometer power rating (to allow safety margin and prevent self heating).
- Does not exceed the +5V_OUT current capacity.

Typically 1 kΩ to 10 kΩ will be preferred.

7.4.5.2 DC tachometer

The Neptune Servo Drive can use a DC tachometer for velocity feedback through the I/O connector. a DC tachometer provides an analog signal whose voltage level is proportional to the rotor speed.

Next figure illustrates how to connect a DC tachometer with differential output to the Neptune Servo Drive.



7.4.6 Feedback wiring recommendations

Signal distortion and electrical noise is a common problem in feedback signals. These problems can result in a bad position or velocity calculation for both digital feedbacks (gain or loss of counts) and analog feedbacks (wrong voltage levels).To minimize these problems some **wiring recommendations** are shown:

- **Use differential signals** whenever is possible. That is, connect both positive and negative signals of differential feedback sensors. **Use a twisted pair for each differential group of signals** and another twisted pair for the +5 V supply and GND. Twisted-pairs help in elimination of noise because disturbances induced in twisted pairs
- Twisted-pairs help in elimination of noise due to electromagnetic fields by twisting the two signal leads at regular intervals. Any induced disturbance in the wire will have the same magnitude and result in error cancellation.
- **Connect the Neptune and encoder GND signals** even if the encoder supply is not provided by the drive.
- **Connection between Neptune PE and the motor metallic housing is essential** to provide a low impedance path and minimize noise coupling to the feedback. For further information, see Protective Earth wiring.
- **For better noise immunity, use shielded cables,** with the shield connected to PE only in the drive side. Never use the shield as a conductor carrying a signal, for example as a ground line.
- It is essential to **keep feedback wiring as far as possible from motor,** AC power and all other power wiring.

7.4.6.1 Recommendations for applications witch close feedback and motor lines

In some applications, like in the subsea market, where additional connectors and cables are a problem, the feedback cannot be wired separately from the motor and power lines. This creates noise problems that could result in hall sensors wrong commutation errors or encoder loss of counts. For these applications we recommend:

- Use a common mode choke on the motor phases. This single action can reduce common mode noise drastically and will solve most problems. See recommended wiring in Motor wiring.
- Ensure the motor housing is well connected to protective earth and the system chassis (PE).
- If possible, minimize power supply voltage. This will also minimize the electromagnetic noise generated by the motor switching.
- Add additional RC low pass filters on the feedback inputs. The filter should attenuate at a frequency above the maximum speed signal to prevent loss of counts and signal distortion. Preferably use resistors with low

values to prevent distortion to the servo drive input circuit at low frequency (< 500 Ω). Use ceramic capacitors with good quality dielectric, like C0G.

For further information contact Ingenia engineers for support.

7.5 I/O connections

The Neptune Servo Drive provides various inputs and output terminals for parameter observation and drive control options. These inputs can also be used for some feedback purposes (see Feedback connections).

The input and output pins are summarized below:

- 2 x 5 V general purpose non-isolated single ended digital inputs (GPI1, GPI2).
- 2 x 5 V high-speed non-isolated differential digital inputs (HS_GPI1, HS_GPI2).
- 1 x 0 ~ 5 V single ended 12 bits analog input (AN_IN1).
- 1 x ±10 V differential 12 bits analog input (AN_IN2).
- 2 x 5 V non-isolated digital outputs (GPO1, GPO2).

Motor brake input

Digital outputs (GPO1 and GPO2) can also be used as a motor brake output.

Wiring recommendations

Wiring recommendations for I/O signals are the same than for feedback signals. Detailed information about good wiring practices can be found in Feedback wiring recommendations.

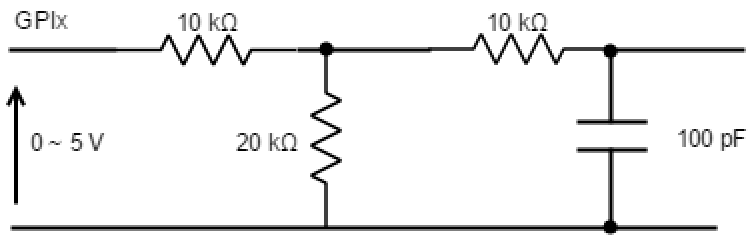
7.5.1 General purpose single ended digital inputs interface (GPI1, GPI2)

The general purpose non-isolated digital inputs are ready for 5 V levels, but are 24 V tolerant. Next table show their electrical specifications.

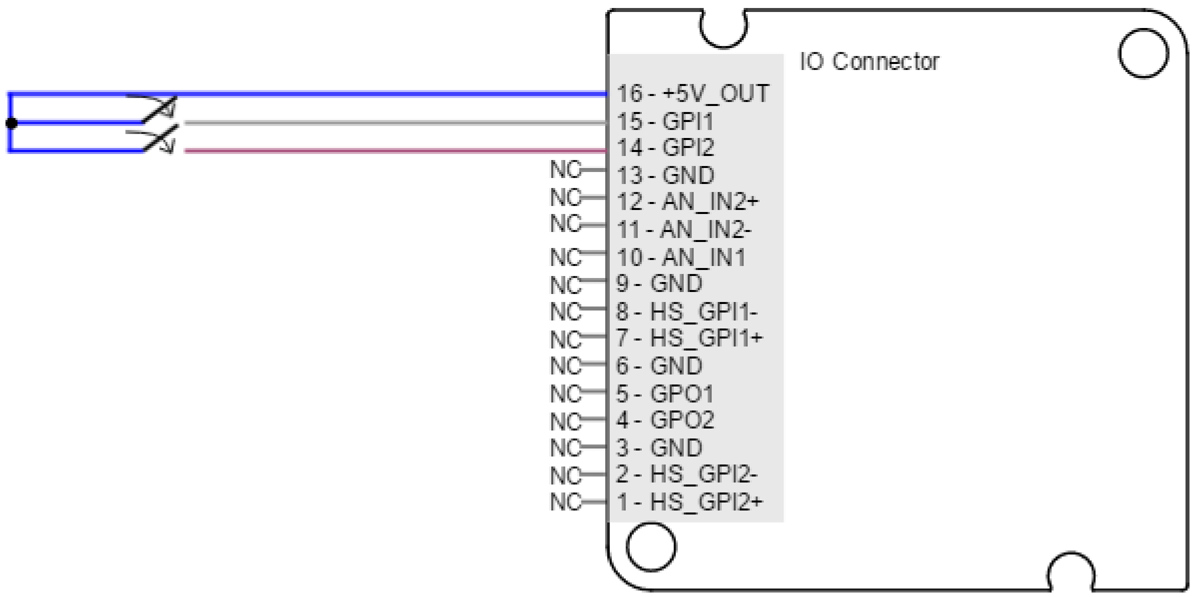
Specification	Value
Number of inputs	2 (GPI1, GPI2)
Type of input	Single ended ESD protected Low-pass filtered
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Input current	0.7 mA @ 5 V; 2 mA @ 15 V
Input voltage range	0V - 30 V
High level input voltage	Vin > 4V
Low level input voltage	Vin < 1 V

Specification	**Value**
Input impedance	30 kΩ
1st order filter cutting frequency (-3 dB)	100 kHz
Sampling rate	1 ksps
Max delay	2 µs

General purpose inputs electrical equivalent circuit is the following:



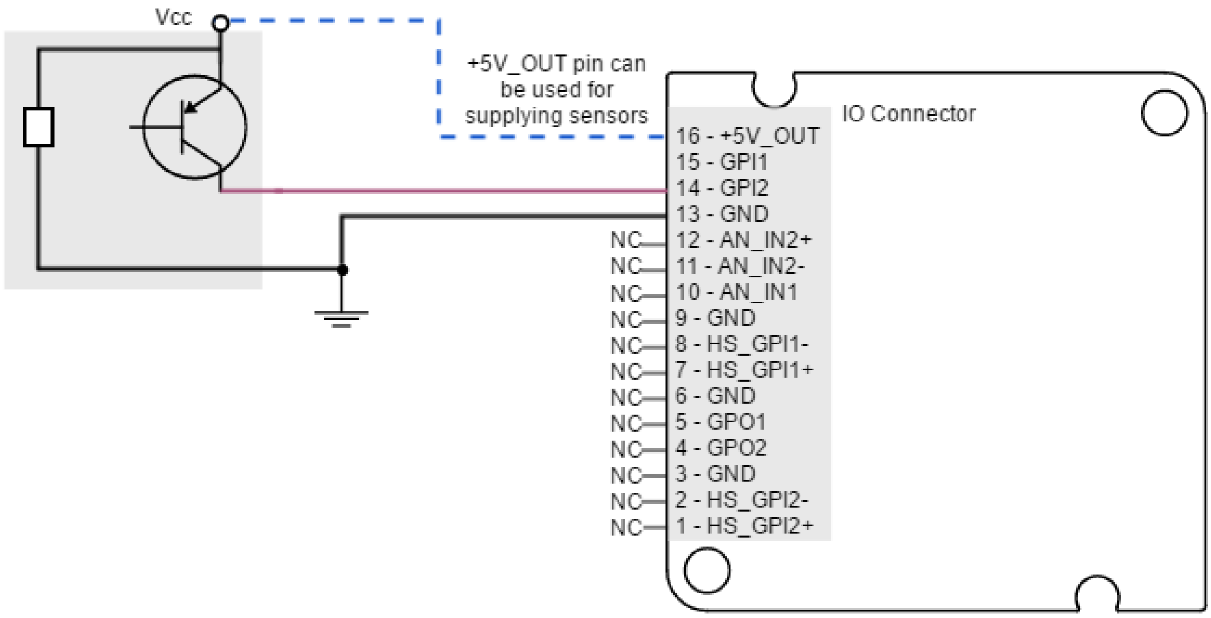
Next figure shows an example of how to connect a switch to the GPI, using +5V_OUT (pin 16) pin as a supply source.

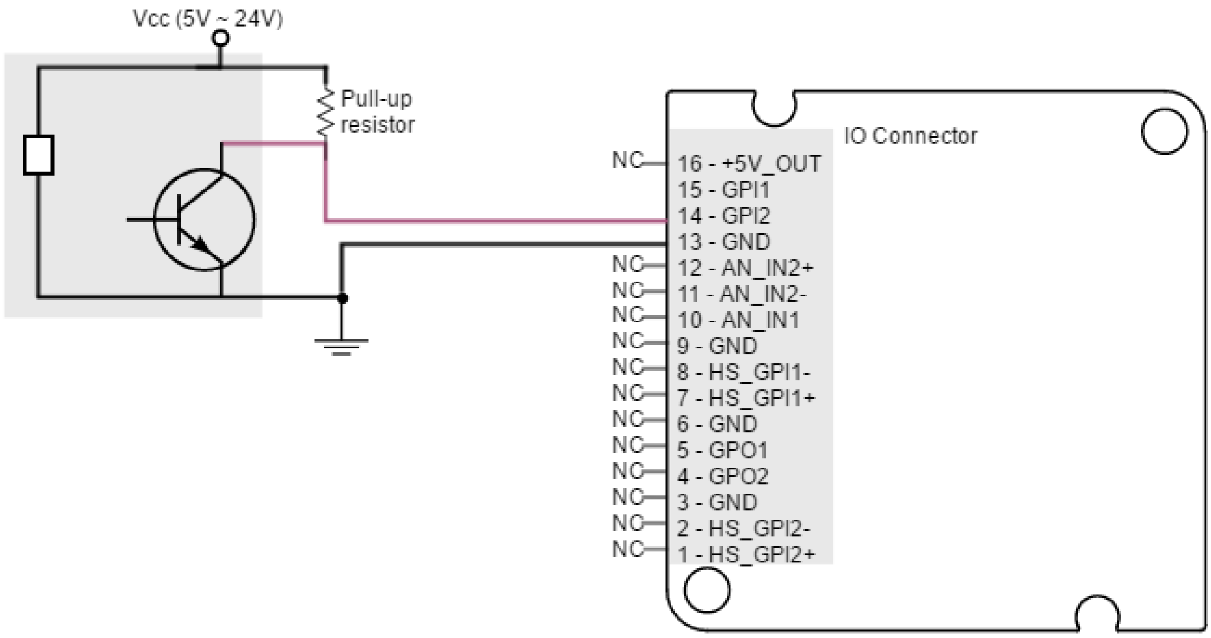


Non-isolated I/O

Neptune Inputs and outputs are not isolated. The ground of the Neptune Servo Drive and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

Neptune Servo Drive general purpose inputs can be used for connecting three-wire sensors. Next figures illustrate the connection of PNP and NPN three-wire sensors in input GPI2 (Same wiring can be used for GPI1). Pin 16 (+5V_OUT) can be used as a supply source.





GPI Pull-up resistors

Pull-up resistors ensure the desired logic state when the sensor (transistor or relay) is in off-state.

NPN pull-up resistor value must be chosen in order to ensure ≥ 4 V at the GPI pin considering the 30 kΩ input resistance. For a sensor supply of 5 V, 1 kΩ is recommended. For a sensor supply of 24 V, 10 kΩ is recommended.

7.5.2 High-speed digital inputs interface (HS_GPI1, HS_GPI2)

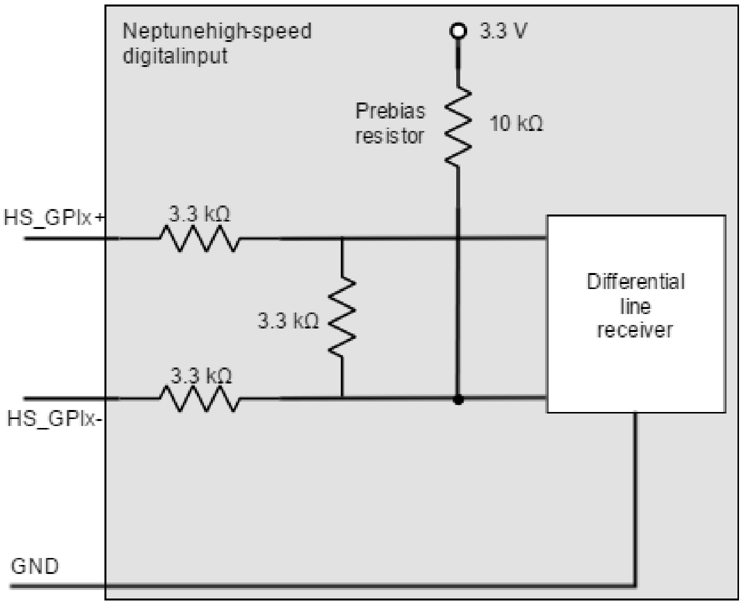
The high-speed (HS) non-isolated digital inputs are ready for 5 V levels but are 24 V tolerant. Next table show their electrical specifications.

> **Defect logic value**
>
> Neptune high-speed inputs are default high-level (ON). When no signal or load connected, the board will detect a logic high.

Specification	Value
Number of inputs	2 (HS_GPI1, HS_GPI2)
Type of input	ESD protected Differential and single ended
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Input current	2 mA @ 5 V; 5 mA @ 15V
High level input voltage	(HS_GPI+ - HS_GPI-) > 150 mV
Low level input voltage	(HS_GPI+ - HS_GPI-) < -600 mV
Maximum working input voltage	±24 V
Maximum recommended frequency	10 MHz
Sampling rate	20 Msps
Total rising delay	65 ns
Total falling delay	55 ns
Maximum common mode voltage (V_{CM})	$-7\ V \le V_{CM} \le 12\ V$

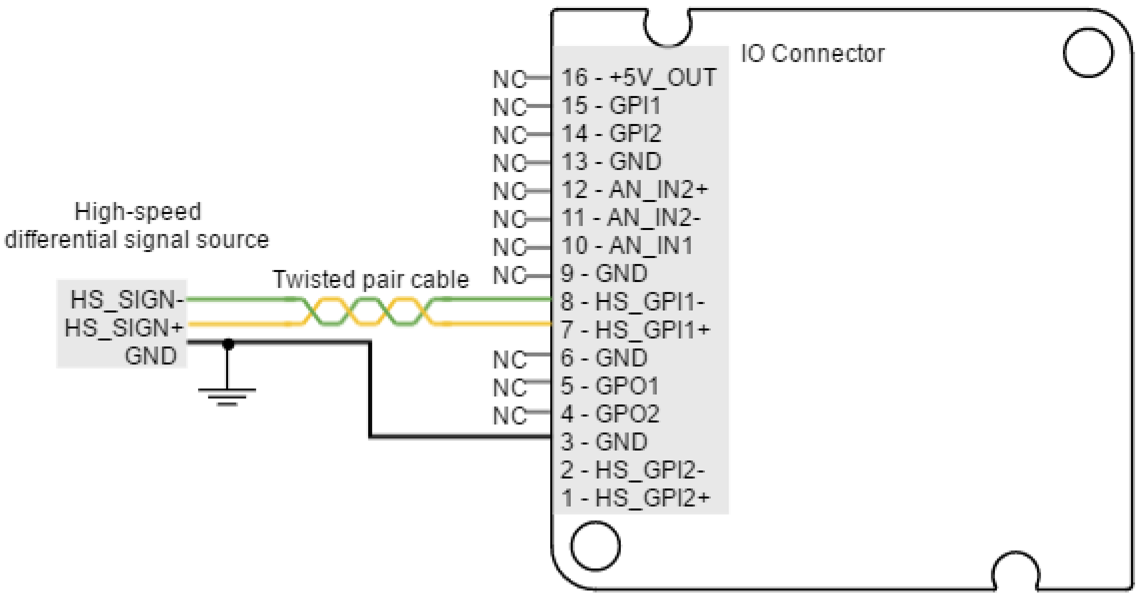
Next figure shows the circuit model for high-speed digital input. Input is composed of a 3-resistor differential divider, with 3.3 kΩ resistors, resulting in a total input impedance of ~10 kΩ. This **bias resistors allow both single ended and differential input operation**. Noise immunity can be improved by reducing input impedance with a termination resistor between HS_GPI+ and HS_GPI-.

High-speed digital inputs electrical equivalent circuit is the following:



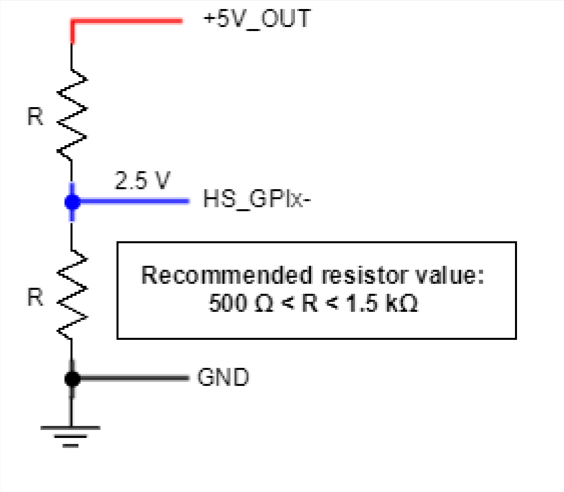
> **Non-isolated I/O**
>
> Neptune Inputs and outputs are not isolated. The ground of the Neptune Servo Drive and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

Next figure illustrates how to connect high-speed differential signal to HS_GPI1 (same wiring can be used for HS_GPI2).



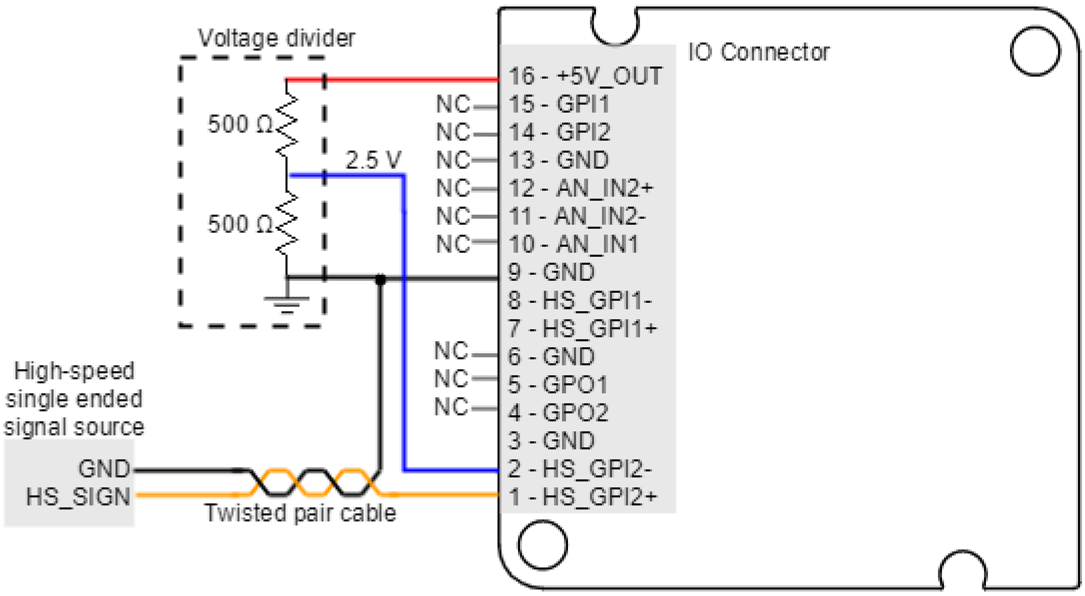
Single ended operation

In order to use the high-speed digital input in **single ended mode**, **connect the negative terminal (HS_GPIx-) to 2.5 V**. This voltage can be achieved with a voltage divider from +5V_OUT.

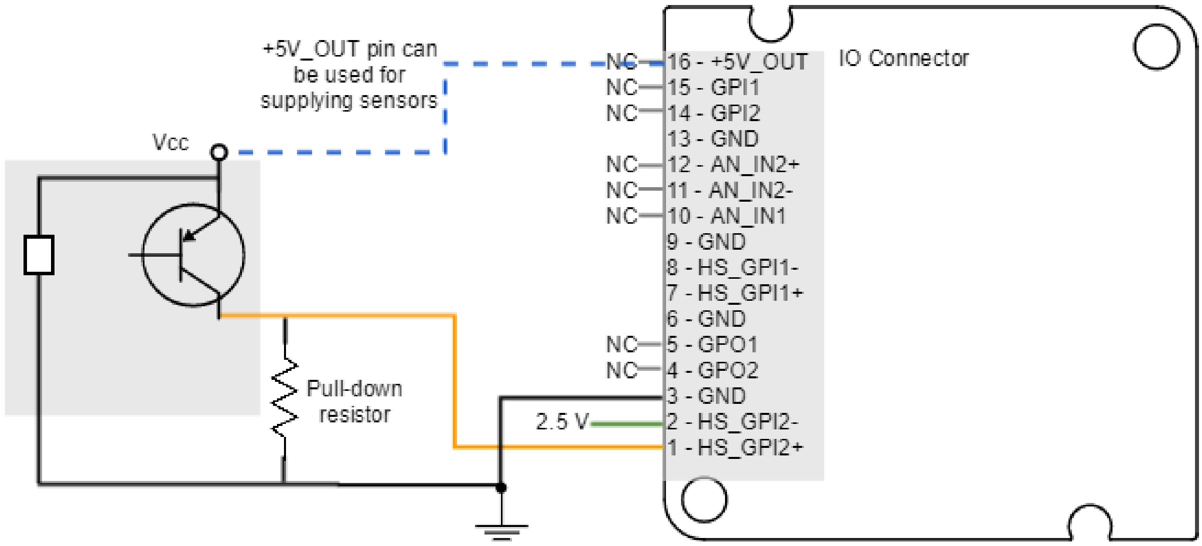


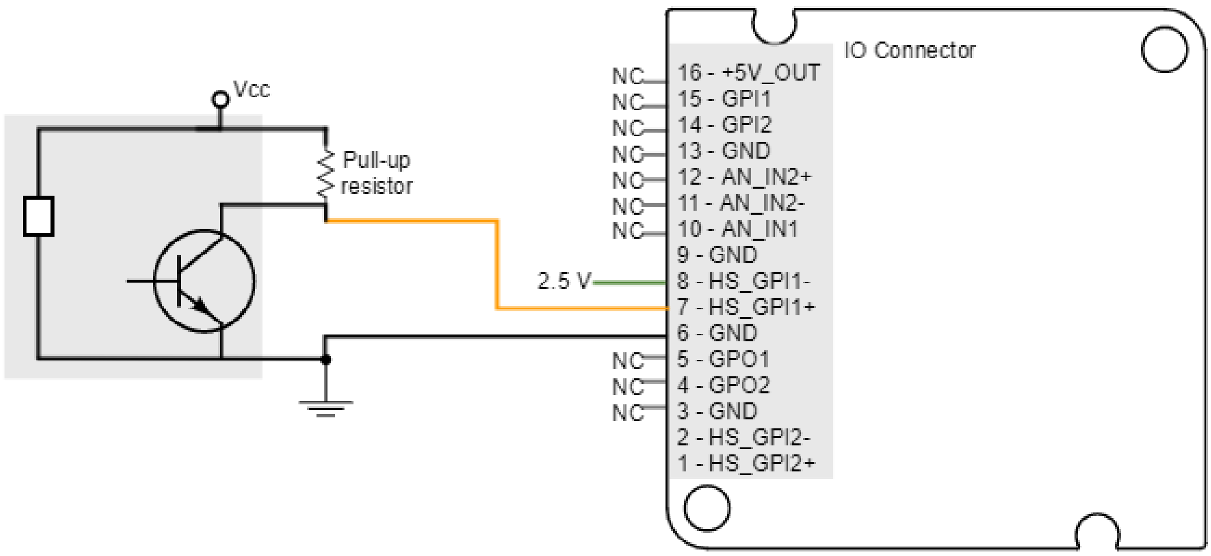
For a 24 V input, the negative terminal **(HS_GPIx-)** can be connected to 5 V (+5V_OUT).

The following figure shows how to connect high-speed **single ended signal** to HS_GPI2 (same wiring can be used for HS_GPI1).



Neptune Servo Drive high-speed digital inputs can be used for connecting three-wire sensors. Next figures illustrate the connection of PNP and NPN three-wire sensors in input HS_GPI2 (Same wiring can be used for HS_GPI1). Pin 16 (+5V_OUT) can be used as a supply source.





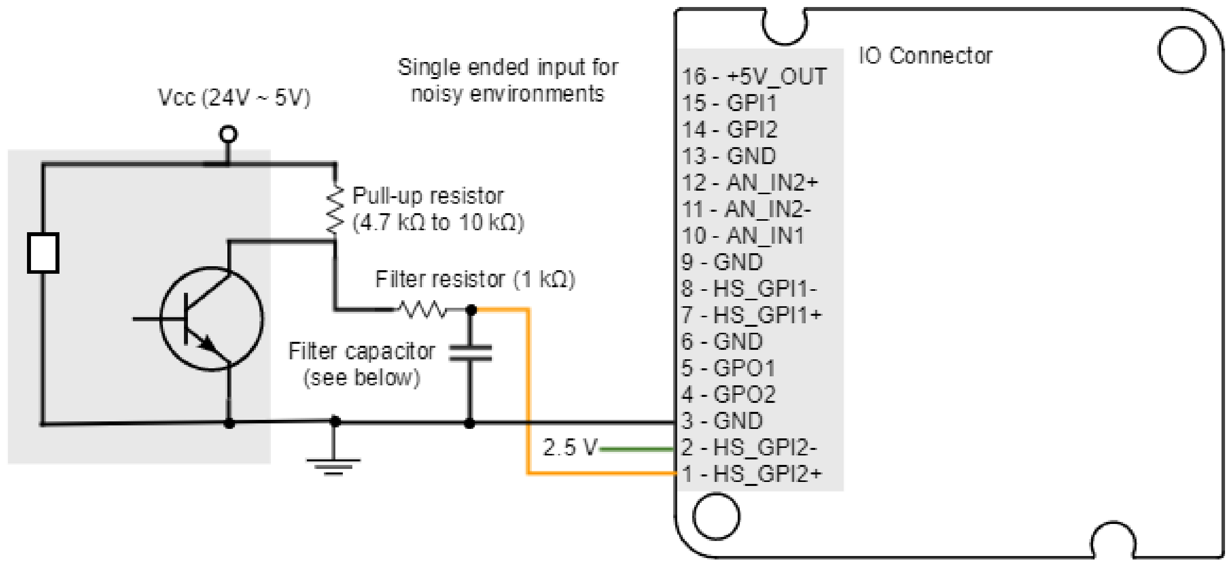
HS_GPI pull-up and pull-down resistors

Pull-up and pull-down resistors ensure the desired logic state when the sensor (transistor or relay) is in off-state.

NPN pull-up resistor value must be chosen in order to ensure a positive value in the differential receiver while consuming low current. For a sensor supply of 5 V, 1 kΩ is recommended. For a sensor supply of 24 V, 10 kΩ is recommended.

PNP pull-down resistor value is not critical. It should be calculated to consume low current when the sensor is on-state. A 10 kΩ resistor is recommended.

The connection of a NPN three-wire sensor with a noise filter is shown in the next figure.



Calculation of the filter capacitor

Cfilter ≤ 1000 / (12 * Freq * (Rfilter + Rpull-up))
Cfilter is in nF. Freq is the maximum signal frequency in kHz. Rfilter and Rpull-up are in kΩ.
Choose the biggest standard capacitance close to Cfilter.
Use ceramic or film (MKP, MKT) capacitors, place them as close as possible to the driver.

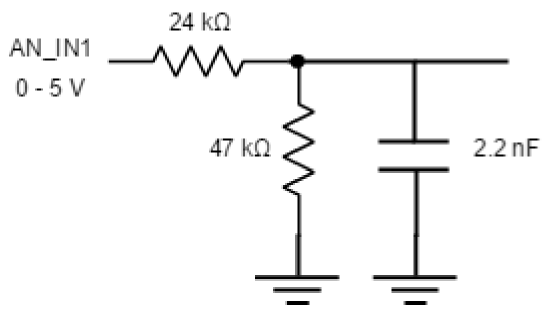
7.5.3 Analog inputs interface (AN_IN1, AN_IN2)

Neptune Servo Drive has two 12-bit analog inputs, a single ended one (AN_IN1) and a differential one (AN_IN2). Each one of them has a different input voltage range. Next table summarizes the main features of the analog inputs:

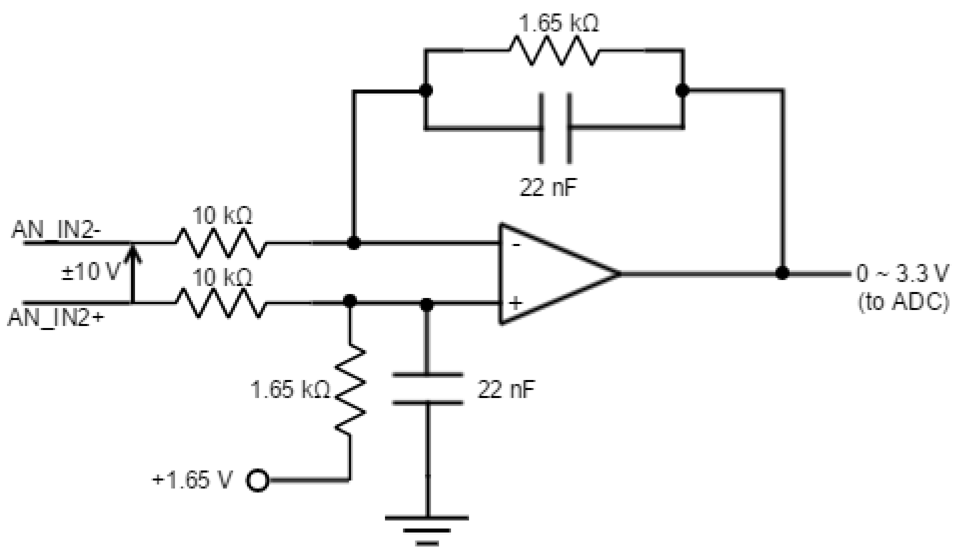
Specification	**Analog input 1**	**Analog input 2**
Type of inputs	Single ended ESD protected	Differential ESD protected
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)	
Analog input resolution	12 bits	
Maximum operating voltage	0 ~ 5 V	±10 V
Maximum common mode voltage (Analog input 2)	-	±10 V
Maximum voltage on any pin (referred to GND)	20 V	
1st order filter cutting frequency (-3dB)	4.5kHz	4.4kHz

Specification	Analog input 1	Analog input 2
Sampling rate (max)	10 ksps	

Next figure shows the circuit model for the analog input 1:



Next figure shows the circuit model for the analog input 2:



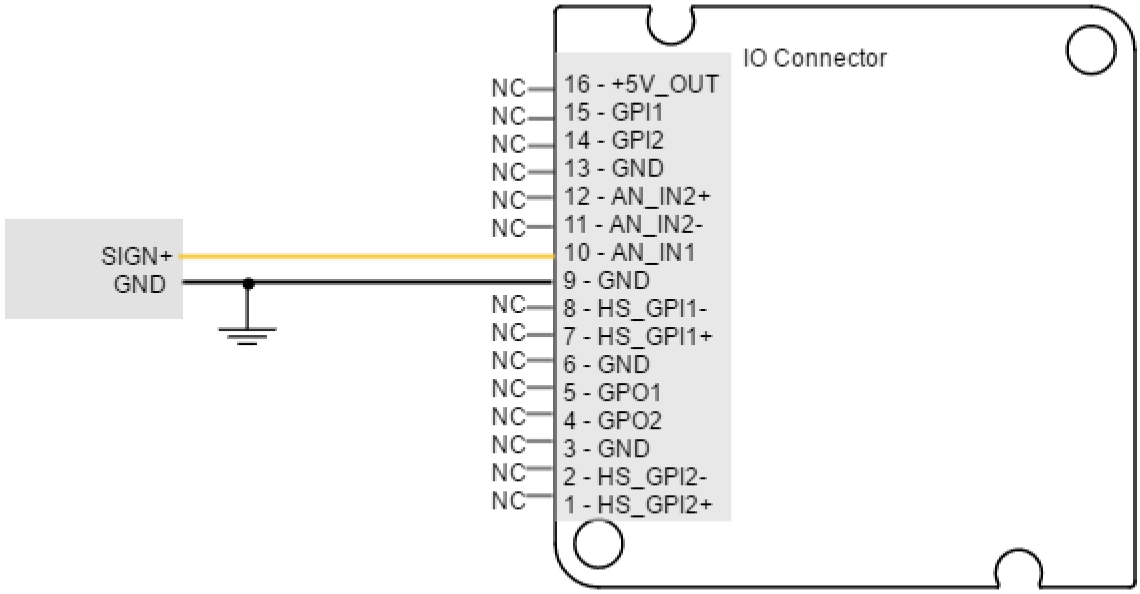
Extending AN_IN1 voltage range

To get a 0 ~ 10 V input range in AN_IN1 input, place a 30 kΩ resistor in series with the input.

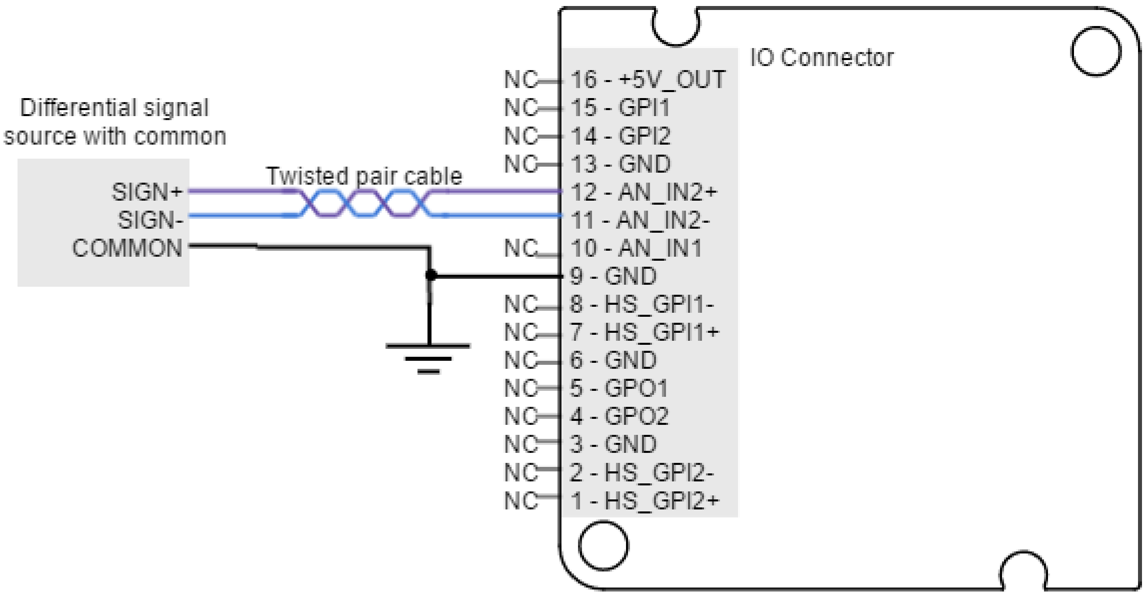
Non-isolated I/O

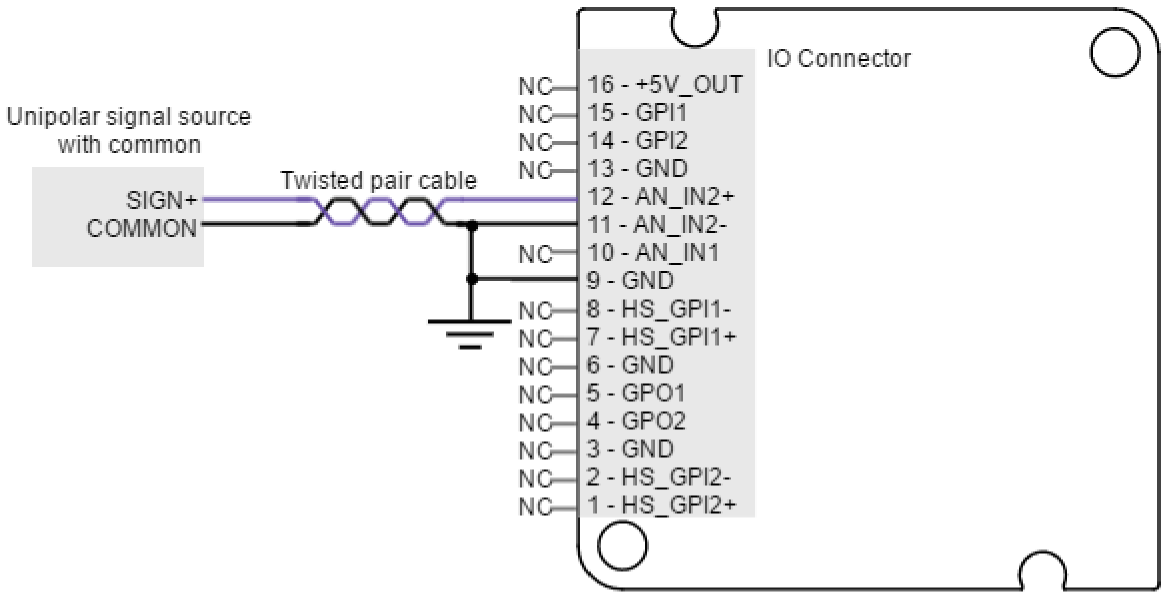
Neptune Inputs and outputs are not isolated. The ground of the Neptune Servo Drive and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

Next figure illustrates how to connect an analog single ended source to the Neptune Servo Drive analog input 1.



Next figure shows how to interface differential and single ended voltage sources to the differential analog input 2. The differential analog input is typically used as a command source or feedback signal.





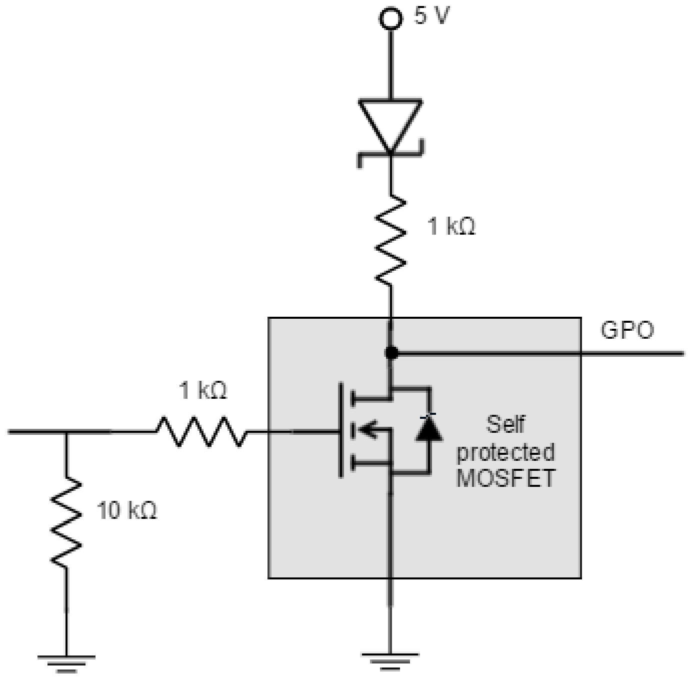
7.5.4 Digital outputs interface (GPO1, GPO2)

Neptune Servo Drive has two digital non-isolated outputs. Digital outputs are based on an open drain MOSFET with a weak pull-up to 5 V, and are 24 V tolerant and short-circuit protected. Next table shows their main features:

Specification	**Value**
Number of outputs	2
Type of output	Open drain output with weak pull-up to 5 V ESD protected Overload, short circuit and over-temperature protected with auto restart (self protected MOSFET).
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Maximum supply output	30 V (5-24 V typical)
Maximum sink/source current	Source: low current @ 5 V: 5 mA Sink: 500 mA @ 5 or 24 V
ON-OFF delay	124 µs @ 30 V and Rload = 100 kΩ 20 µs @ 5 V and Rload = 100 kΩ

Specification	Value
OFF_ON delay	15μs @ 30 V and Rload = 100 kΩ 50 μs @ 5 V and Rload = 100 kΩ
Max working frequency	1 kHz

Next figure shows digital outputs circuit model.

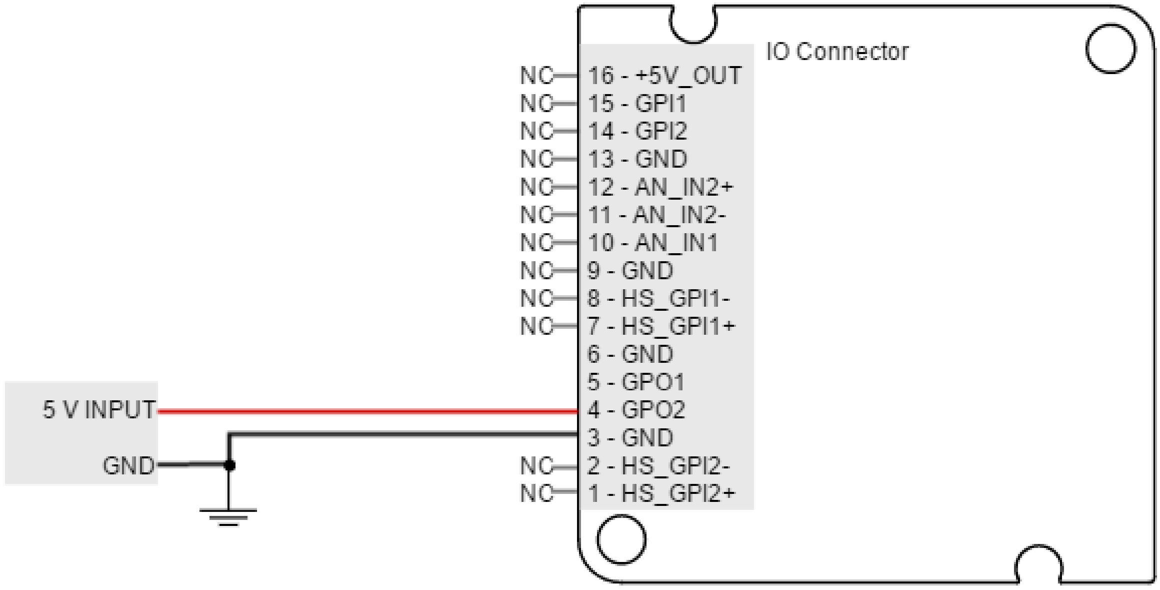


Non-isolated I/O

Neptune Inputs and outputs are not isolated. The ground of the Neptune Servo Drive and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

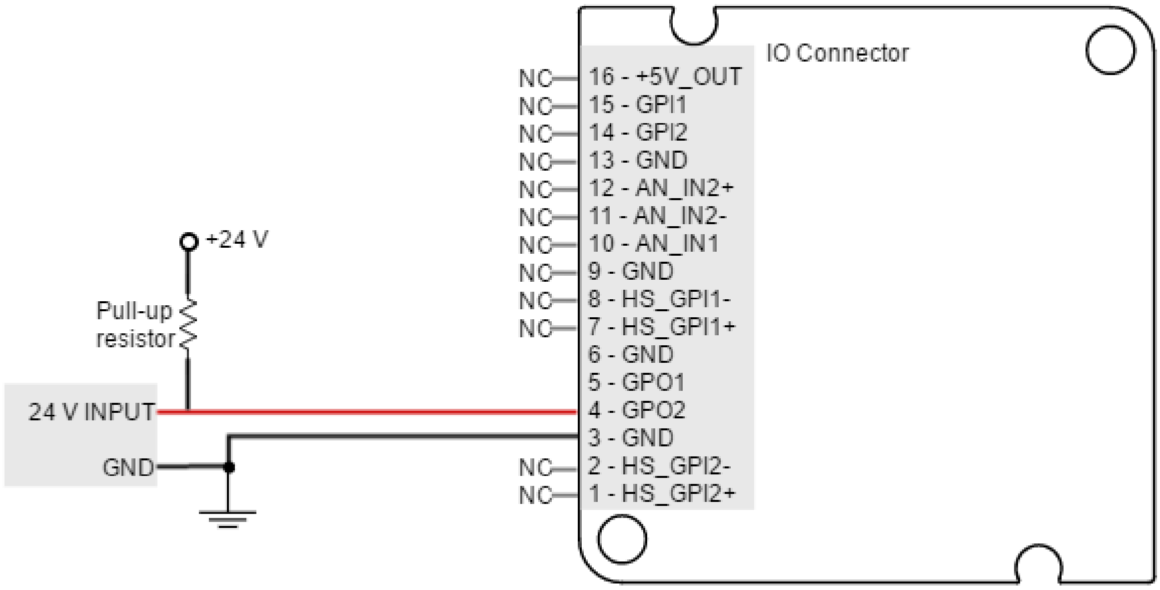
7.5.4.1 Wiring of 5V loads

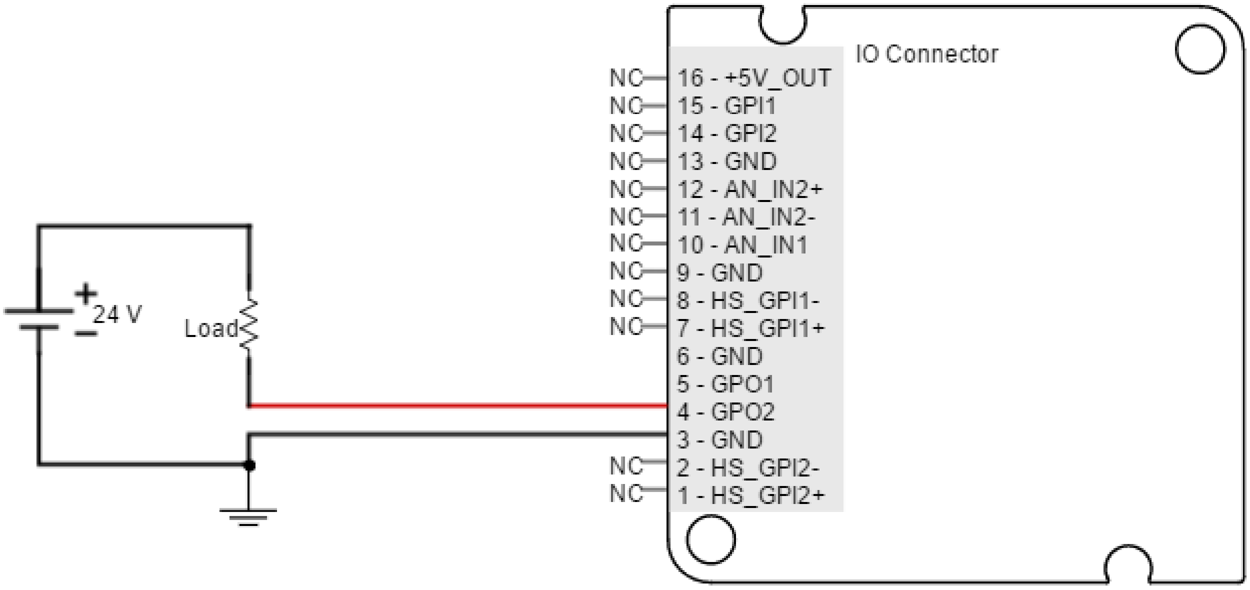
Loads that require 5V as high-level voltage can be connected directly to the digital output. A wiring example for GPO2 is shown in the next figure (same wiring could be used for GPO1).



7.5.4.2 Wiring of 24V loads

Loads that require 24V as high-level voltage can also be interfaced with GPO. For this option, an external power supply is needed. The load can be connected with a pull-up to 24V or directly switched with the GPO. Next figures show two example connections to GPO2 (same wiring could be used for GPO1).





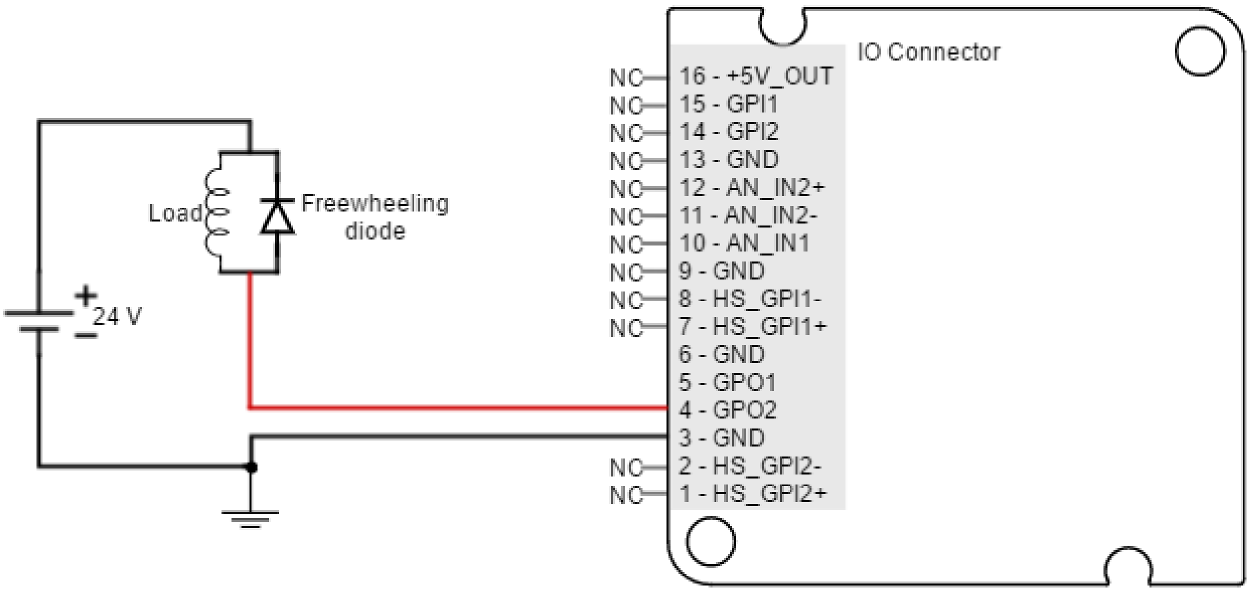
Interfacing inductive loads

The switching of inductive loads (like relays or motor brakes) can cause inductive kicking, that is a sudden voltage rise when the current through the inductor is falls to zero. In order to avoid this voltage rise, **it is recommended to place a diode in anti-parallel with the load** (known as freewheeling diode).

Standard rectifier diodes such as 1N4002 or 1N4934 are appropriate for the application.

An alternative to the freewheeling diode is to place a varistor or an RC snubber in parallel with the load.

An example of how to connect an inductive load to GPO2 is shown in the next figure (same wiring could be used for GPO1).



7.5.5 Motor brake output (GPO1, GPO2)

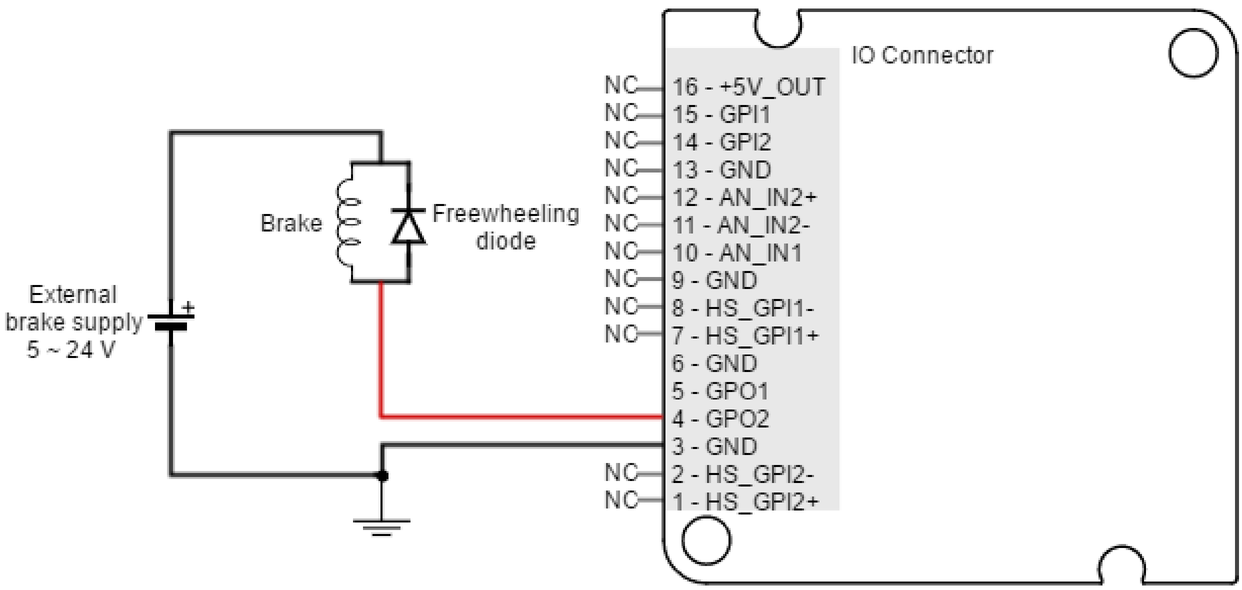
Electromechanical brakes are needed in critical applications where the disconnection of the motor or a lack of electric braking could be dangerous or harmful (i.e. falling suspended loads). Neptune Servo Drive can use the digital outputs (GPO1 and GPO2) as a brake output. This output consists on an open drain MOSFET (1 A and 24 V). Further specifications can be found in Digital outputs interface.

Motor brake operation

For brake operation of a GPO, this function has to be configured through Motion Lab.

The brake operation is usually configured for normally locked electromechanical brakes; that is, brakes that by default block the movement of the motor shaft. For this reason, **the switch is controlled with inverted logic, being activated to allow the rotation of the shaft**. This kind of brakes increase the safety of the application, because in a drive power failure, the switch would be opened and therefore the brake activated.

Next figure show how the typical connection using the main supply as brake power supply.



Free-wheeling diode

It is recommended to use a freewheeling diode in anti-parallel with the brake to prevent inductive kicking (voltage rise when current through the brake inductance falls to zero). Standard rectifier diodes such as 1N4002 or 1N4934 are appropriated for the application.

7.6 Command sources

The target or command sources are used for setting a reference for position, velocity or torque controllers. Neptune Servo Drive supports the following command sources:

- Network communication interface (USB, CANOpen, RS-232 or EtherCAT)
- Standalone
- Analog input (±10 V or 0 V to 5 V)
- Step and direction
- PWM command (single and dual input mode)
- Encoder follower / electronic gearing.

Analog inputs, step and direction, PWM command and encoder follower / electronic gearing are interfaced through general purpose inputs. Next table illustrates which variables can be controlled with each command source:

Command source	**Target variable**
Network interface	Position, velocity, torque
Standalone	Position, velocity, torque
Analog input (+/- 10 V o 0 – 5 V)	Position, velocity, torque
Step and direction	Position
PWM command	Position, velocity, torque
Encoder following / electronic gearing	Position

Please, see Command sources section from E-Core documentation for configuration details.

7.6.1 Network communication interface

Neptune Servo Drive can utilize network communication as a form of input command. Supported network interfaces for Neptune Servo drive are CAN (CANopen protocol), USB, RS232 and EtherCAT.

USB and RS232 interfaces are not suitable for long distances or noisy environments. These protocols are only recommended for configuration purposes.

For normal operation, it is suggested to use CAN or EtherCAT. These interfaces are more robust against noise than USB and RS232, and allow higher distances between the Neptune Servo Drive and the commander. These command sources can be used for setting position, velocity or torque target.

For further information, see Communications section.

7.6.2 Standalone

Neptune Servo Drive is provided with an internal non-volatile memory where a standalone program can be saved. With the use of Ingenia Motion Lab suite, the user can configure and save instructions to this 1 Mb (128K x 8bit)

EEPROM, allowing Neptune Servo Drive to work in standalone mode. In this mode, there is no need of any external command source.

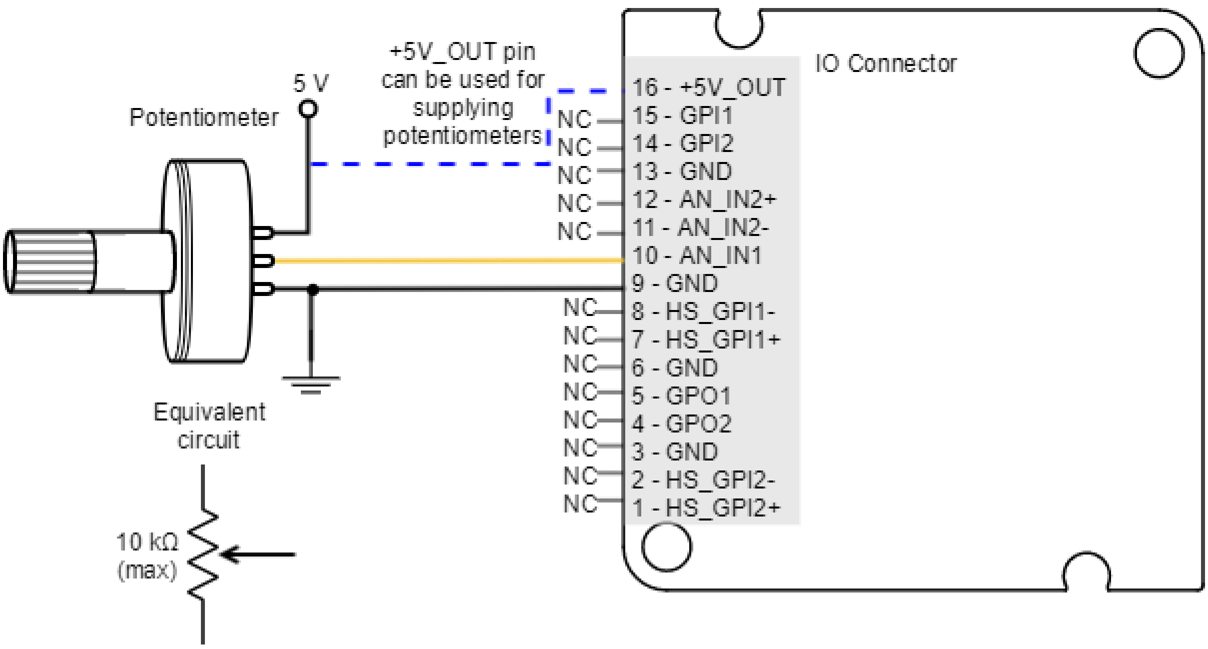
Programs or macros composed with Motion Lab suite allow to **configure position, velocity or torque targets** and to **interface with general purpose inputs and outputs.**

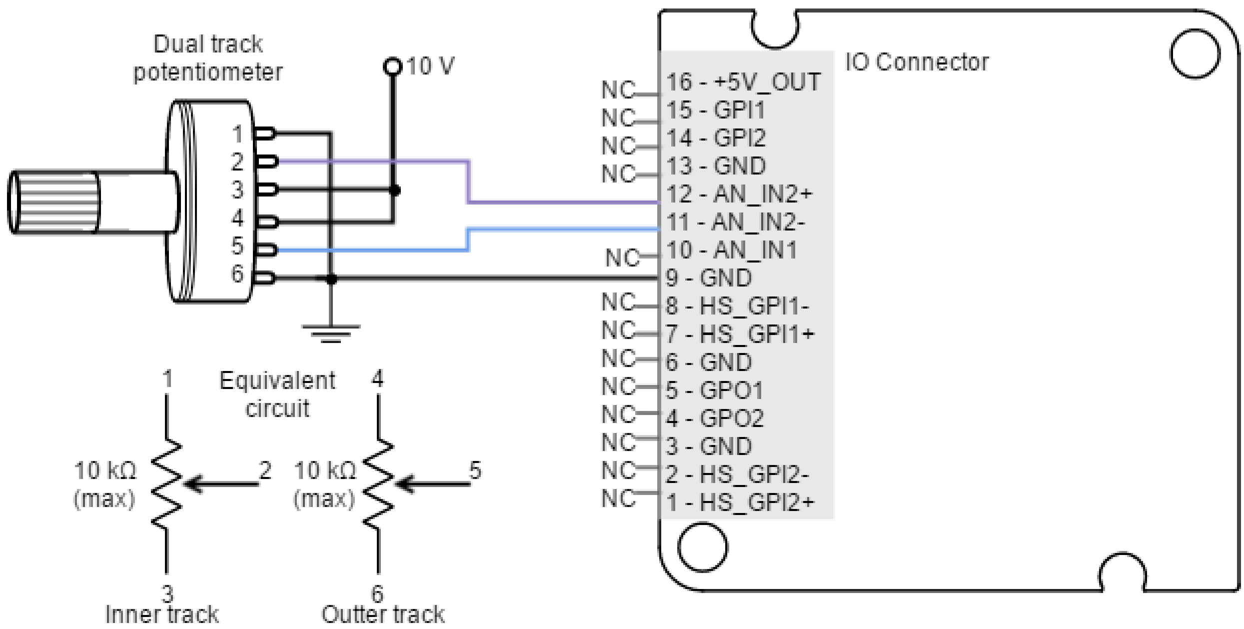
This feature can be very useful in applications such as production lines or test equipment, where repetitive movements are usual. Please refer to MotionLab documentation for further information.

7.6.3 Analog input

Position, velocity or torque targets can also be controlled trough an analog signal. Any general purpose analog input can be used as command source. Neptune Servo Drive has two 12-bit analog inputs, a single ended one with 0 V to 5 V range (AN_IN1) and a differential one with +/-10 V range (AN_IN2). Refer to I/O Connections for further details about analog inputs.

A common application of the analog command source is the use of joysticks (or other kinds of potentiometers) for controlling the position or velocity of a system. As application examples, the following figures show how to connect a potentiometer to the single ended analog input (AN_IN1) and a dual track potentiometer to the differential analog input (AN_IN2).

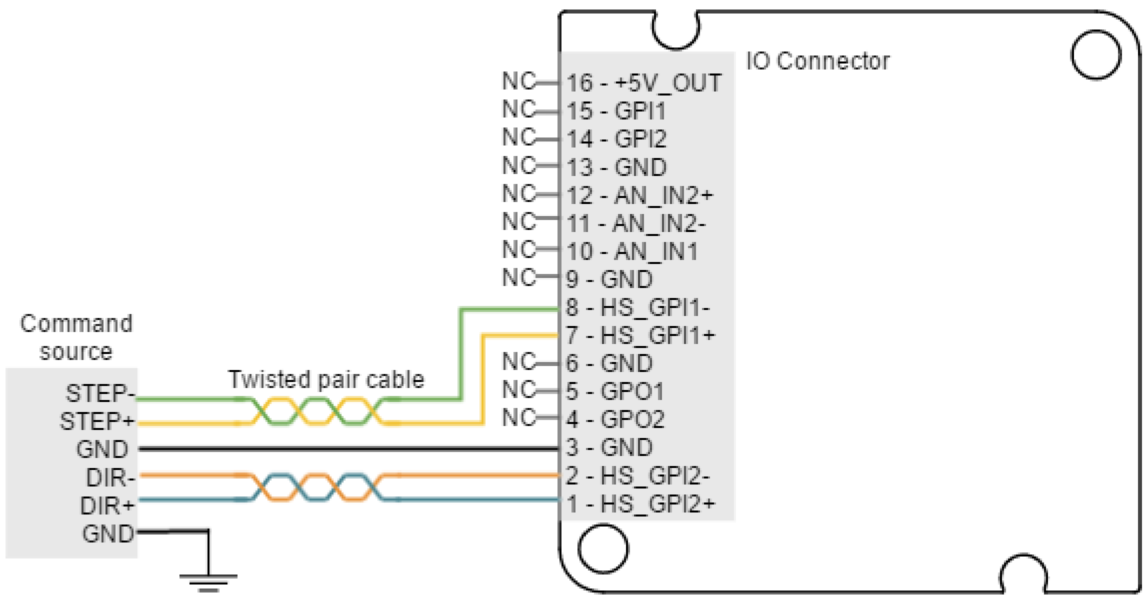




7.6.4 Step and direction

For this command source, the drive typically accepts two digital inputs from an external source: Step (pulse) and Direction. Direction signal sets the direction of rotation (i.e., logic low or "0" for clockwise rotation and logic high or "1" for counter-clockwise rotation). Pulse signal is usually a square signal and each pulse on this signal causes the controller to move the motor one step in that direction. This command source can be used only for position mode.

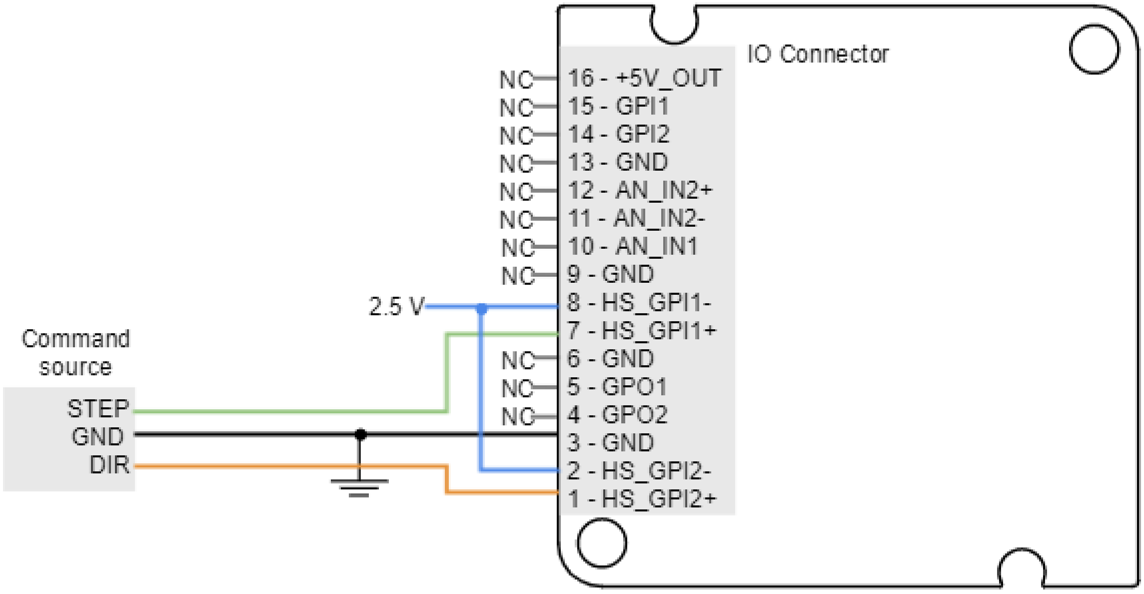
This command source is interfaced through high-speed digital inputs. HS_GPI1 is used for Step input, and HS_GPI2 is used for Direction input. Refer to I/O Connections for further specifications about high-speed digital inputs. Next figures illustrate how to connect a single ended and differential step and direction command source to the Neptune Servo Drive.



Single ended operation

In order to use the high-speed digital input in **single ended mode**, **connect the negative terminal (HS_GPIx-) to 2.5 V**. This voltage can be achieved with a voltage divider from +5V_OUT.

For a 24 V input, the negative terminal **(HS_GPIx-)** can be connected to 5 V (+5V_OUT).



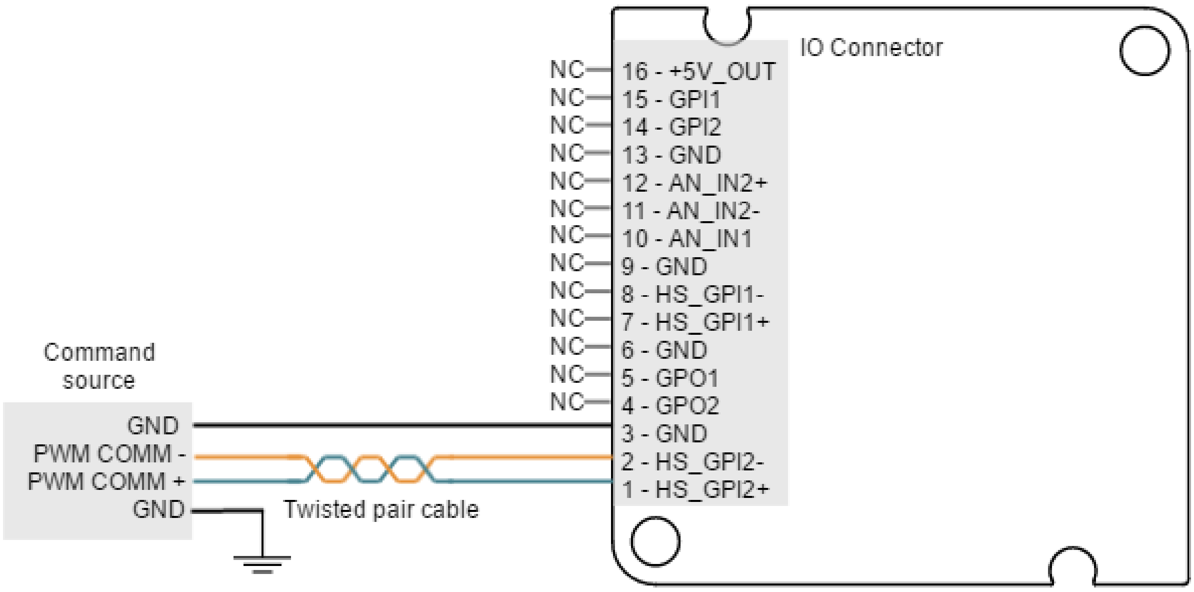
7.6.5 PWM command

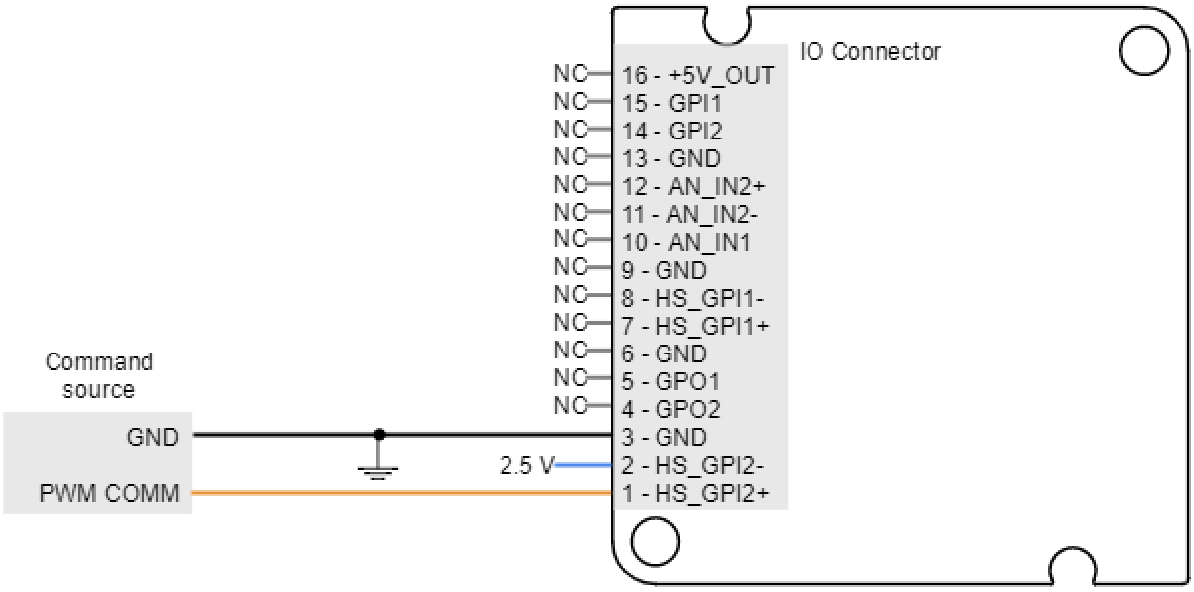
PWM command source sets a position, velocity or torque target from the duty cycle value of a PWM signal. PWM command has to be interfaced with the **high-speed digital input 2 (HS_GPI2)**. Further details about this input can be seen in I/O Connections page. PWM command sources with single and dual input modes can be used.

7.6.5.1 Single input mode

Single input mode is based o the use of a PWM signal whose duty cycle sets the target position, velocity or torque. A duty cycle of 50% corresponds with a target of 0 rad, 0 rpm or 0 N·m, and higher or lower values indicate the target in a different rotating direction. That is, a duty cycle of 0% corresponds with the maximum position, velocity or torque in one direction, and a 100% duty corresponds to the maximum position, velocity or torque in the opposite direction.

Examples of single input mode PWM command in differential and single ended connections are shown in the next figures.





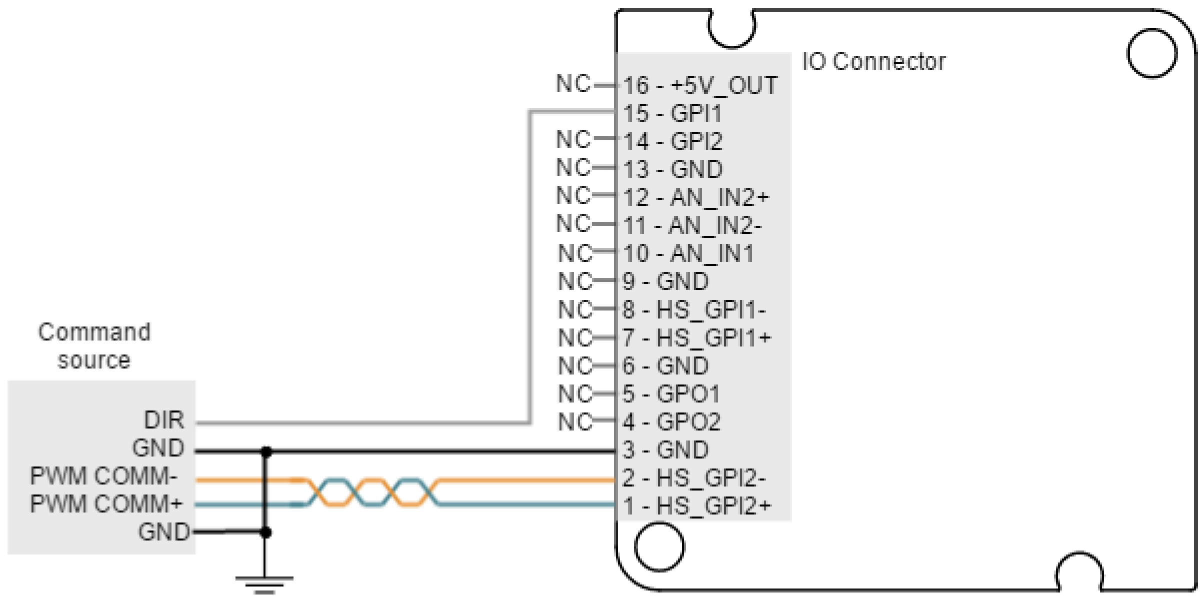
7.6.5.2 Dual input mode

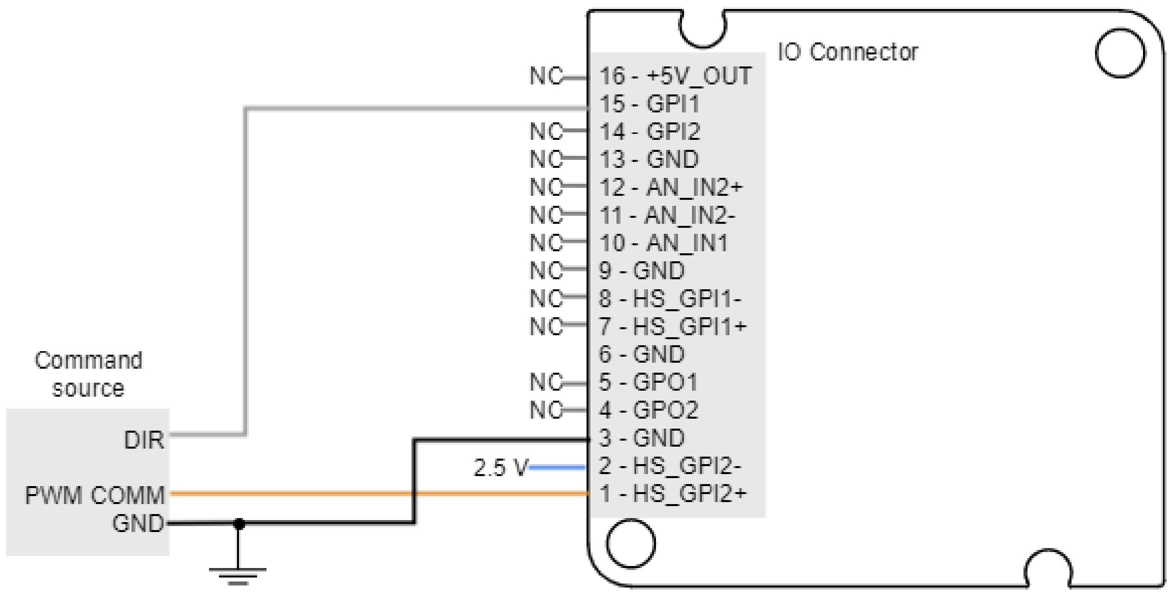
Dual input mode uses two signal lines, a PWM signal whose duty cycle sets the target position, velocity or torque, and a Direction signal that indicates the rotation direction (i.e., logic low or "0" for clockwise rotation and logic high or "1" for counter-clockwise rotation). In this mode, a duty cycle of 0% corresponds with a target of 0 rad, 0 rpm or 0 N·m, and a duty cycle of 100% corresponds to the maximum position, velocity or torque.

Two general purpose inputs are used:

- High speed digital input 2 (HS_GPI2) for PWM Command
- General purpose digital input 1 (GPI1) for Direction.

Examples of dual input mode PWM command in differential and single ended connections are shown in the next figures.

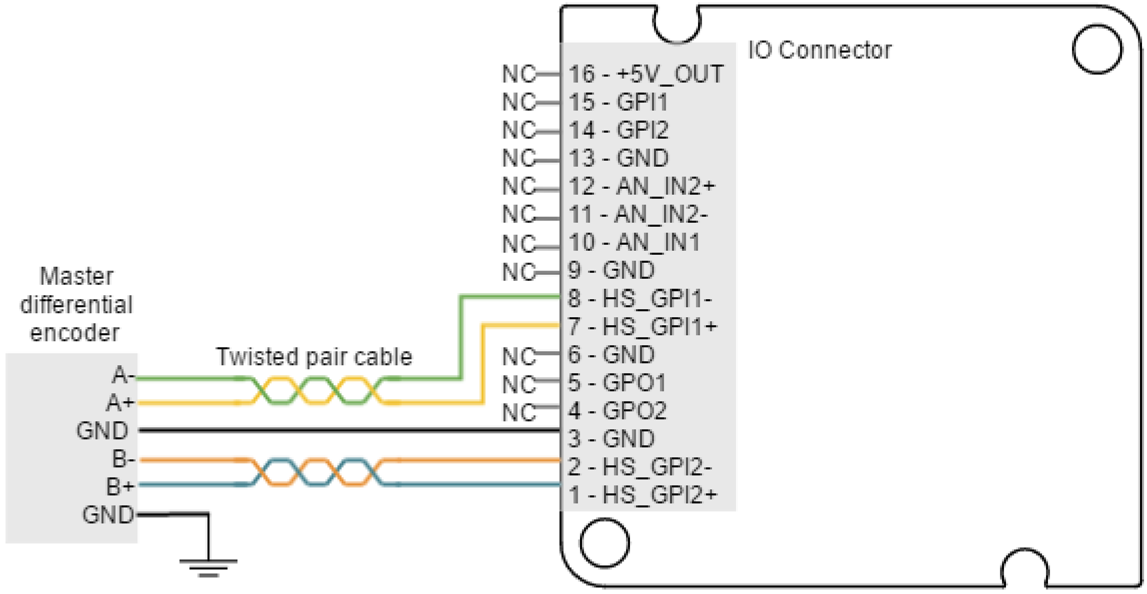


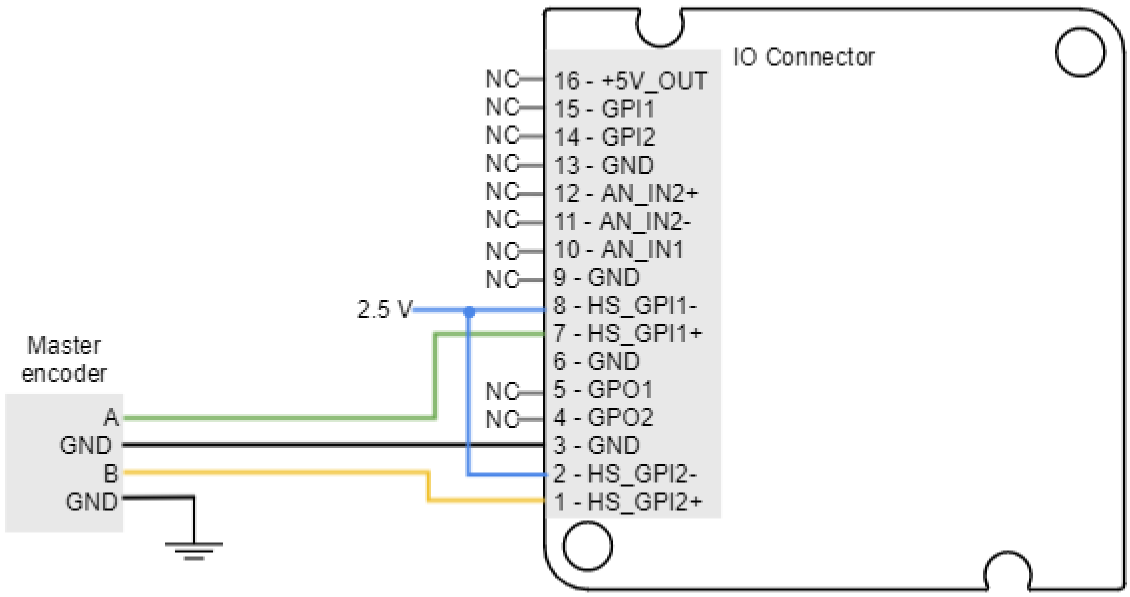


7.6.6 Encoder following or electronic gearing

Encoder following command source is used tor **drive two motors to the same position**. The encoder (or an auxiliary encoder) of the master motor is read by the Neptune Servo Drive and used as position target. A gearing ratio between the motors (input counts to output counts ratio) can be configured via software.

Encoder following command source is implemented by connecting the input encoder (auxiliary encoder of the master motor) to high-speed digital inputs (HS_GPI). Encoder channel A must be connected to high speed digital input 1, and channel B to high speed digital input 2. Connection examples for the differential and single ended master encoders are shown in the next figures:





7.7 Communications

The Neptune Servo Drive provides the following network communication interfaces for configuration and operation:

- USB
- Serial interface - RS232
- CANopen
- EtherCAT

All the interfaces can be used to connect the Neptune with Ingenia Motion Lab suite or a custom application built with the supplied controller libraries. With the objective of configure and diagnostic CAN communication, CANopen and another communication interface can be used simultaneously.

7.7.1 USB interface

Neptune Servo Drive supports Universal Serial Bus (USB), a standard interface for connecting peripheral devices to a host computer. The following table shows main USB interface specifications:

Specification	Details
USB version	USB 2.0 (full speed)
Data rate	Up to 12 Mbps
Maximum cable length	5 meters (16 feet)

USB application

USB interface is only recommended for configuration purposes. For noisy environments, CANopen interface is strongly recommended.

7.7.1.1 USB powered drive

The Neptune can be powered from USB for configuration purposes without the need of an external power supply. With USB supply the Neptune is not capable of driving a motor, but communications, feedbacks and IOs are fully functional. An internal switch automatically chooses the power source prioritizing the Supply and shunt connector. Please note that several functionalities will not be available when powered from USB.

7.7.1.2 USB wiring recommendations

Although USB is a widespread communication standard it has some disadvantages when operating in noisy environments. Following are some wiring recommendations.

- Use shielded cable with the shield connected to PC end. Shield of micro USB connector is **not** connected on Neptune.
- Do not rely on an earthed PC to provide the Neptune Servo Drive earth connection. The drive must be earthed through a separate circuit.
- Avoid creating ground loops by using isolated power supplies.

- Shortest cables are preferred.

7.7.2 RS232 interface

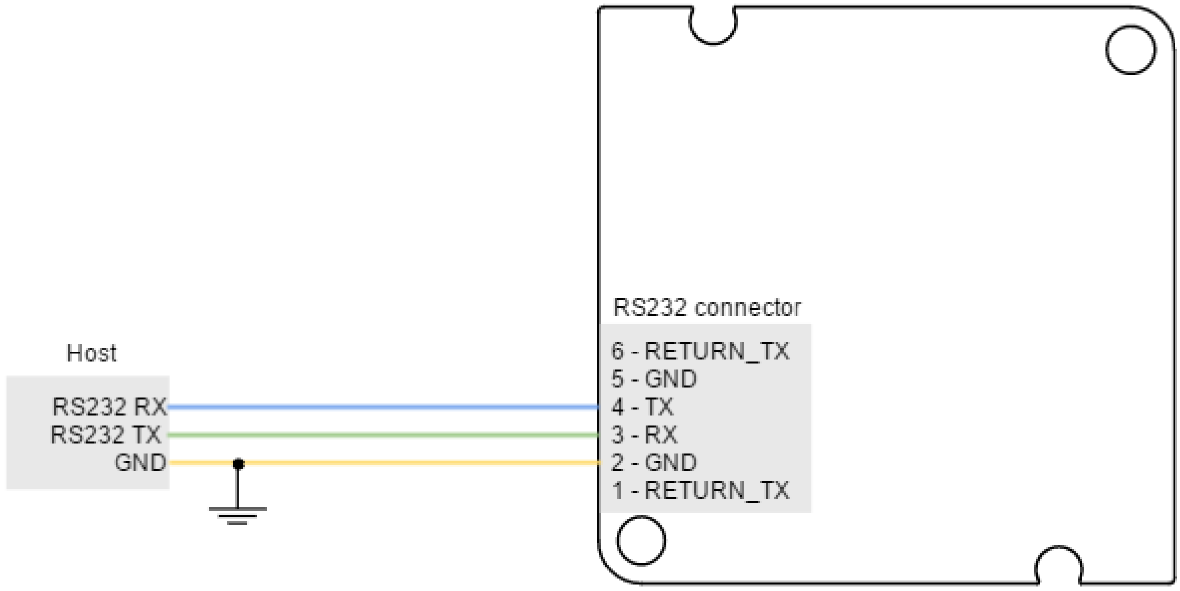
Neptune Servo Drive supports RS232 interface. Following table shows some specifications of the Neptune RS232 interface:

Specification	Details
Interface	Non-isolated Self-supplied (no need for external supply) Simplex, half-duplex and full-duplex
Baud rate	9600 bps to 115200 bps (default value)
Communication distance	Up to 15 m
Daisy chain	Supported

RS232 application

RS232 interface is only recommended for configuration purposes. For noisy environments, CANopen interface is strongly recommended.

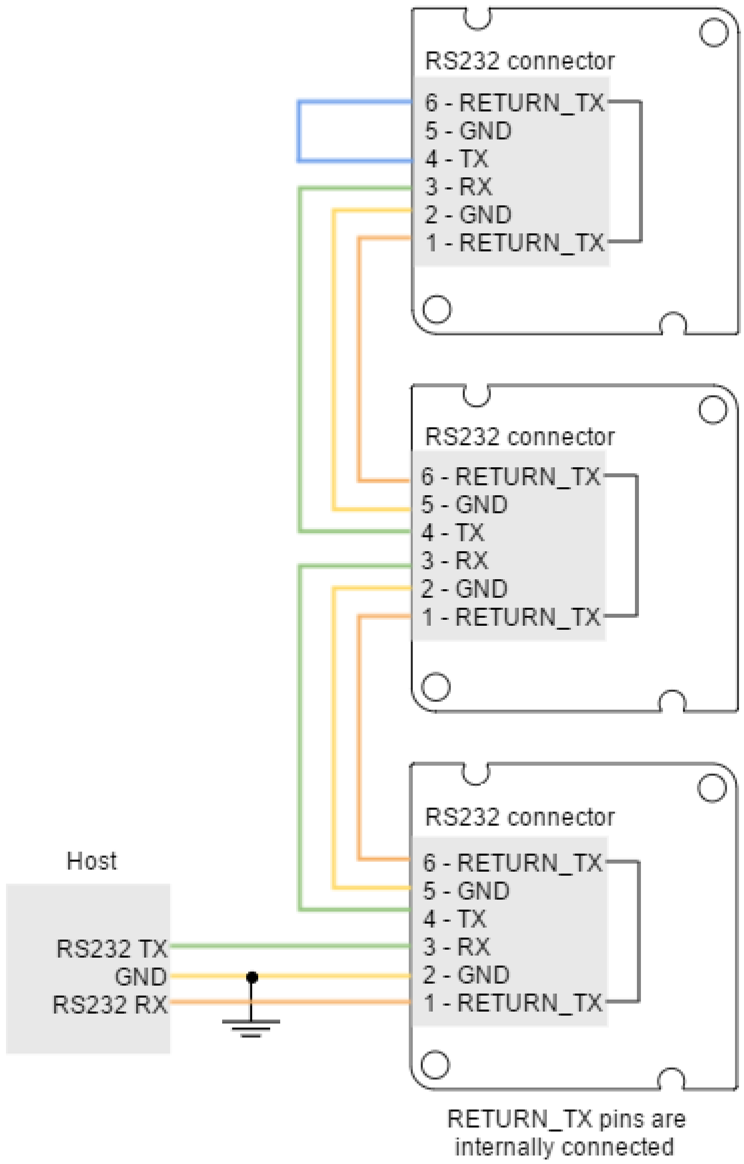
Next figure illustrates how to connect Neptune Servo Drive with a host in a point to point configuration.



> **Multi-point connection**
>
> Neptune Servo Drive **RS232 interface allow multi-point connection using daisy chain connection.**
>
> Multiple drive connection with daisy chain **must be configured using Ingenia** Motion Lab **suite.** For allowing multi-point communication **each servo drive must be allocated a unique node ID**, and **daisy chain option must be enabled.** Please, see UART configuration section in E-Core documentation for further information.

7.7.2.1 Multi-point connection using daisy chain

Daisy chain connection is a multi-point network topology based on connecting multiple terminals in a ring. The wiring consists on connecting the TX terminal of each device to the RX terminal of the next device. With the use of RETURN_TX terminal (which directly connects terminals 1 and 6) daisy chain wiring can be simplified. An example of RS232 daisy chain wiring is shown in the next figure.



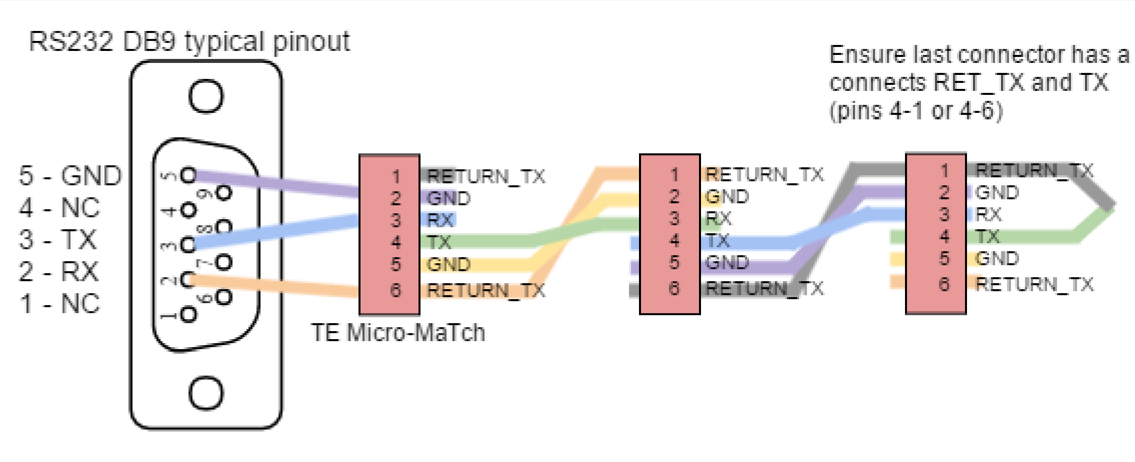
Daisy chain clever wiring with flat cable

The Neptune Servo Drive RS232 connector allows to implement a daisy chain using 6 way 1.27 pitch flat ribbon cable. This solution highly simplifies the wiring.

The use of RETURN_TX pin simplifies the wiring and maximizes EMI immunity due to minimum ground loop and close returns for TX and RX.

To implement an RS232 daisy chain cable follow next steps:

1. Crimp the first connector in the ribbon cable.
2. Cut lines 1, 2 and 3 (RETURN_TX, GND, RX).
3. Twist the cable once and connect lines 4, 5 and 6 (TX, GND, RETURN_TX) to pins 1, 2 and 3 to the next connector.
4. Repeat until the last device
5. On the last device, connect TX and RETURN_TX (lines 4-1 or 4-6).



7.7.2.2 RS232 wiring recommendations

Although RS232 is a widespread communication standard it has some disadvantages when operating in noisy environments. Following are some wiring recommendations.

- Use 3-wire shielded cable with the shield connected to Neptune Servo Drive end. Do not use the shield as GND. The ground wire must be included inside the shield, like the RX and TX signals.
- Do not rely on an earthed PC to provide the Neptune Servo Drive earth connection. The drive must be earthed through a separate circuit. Most communication problems are caused by the lack of such connection.
- Ensure that the shield of the cable is connected to the shield of the connector used for communications.
- Avoid creating ground loops.
- Shortest cables are preferred

7.7.3 CANopen interface

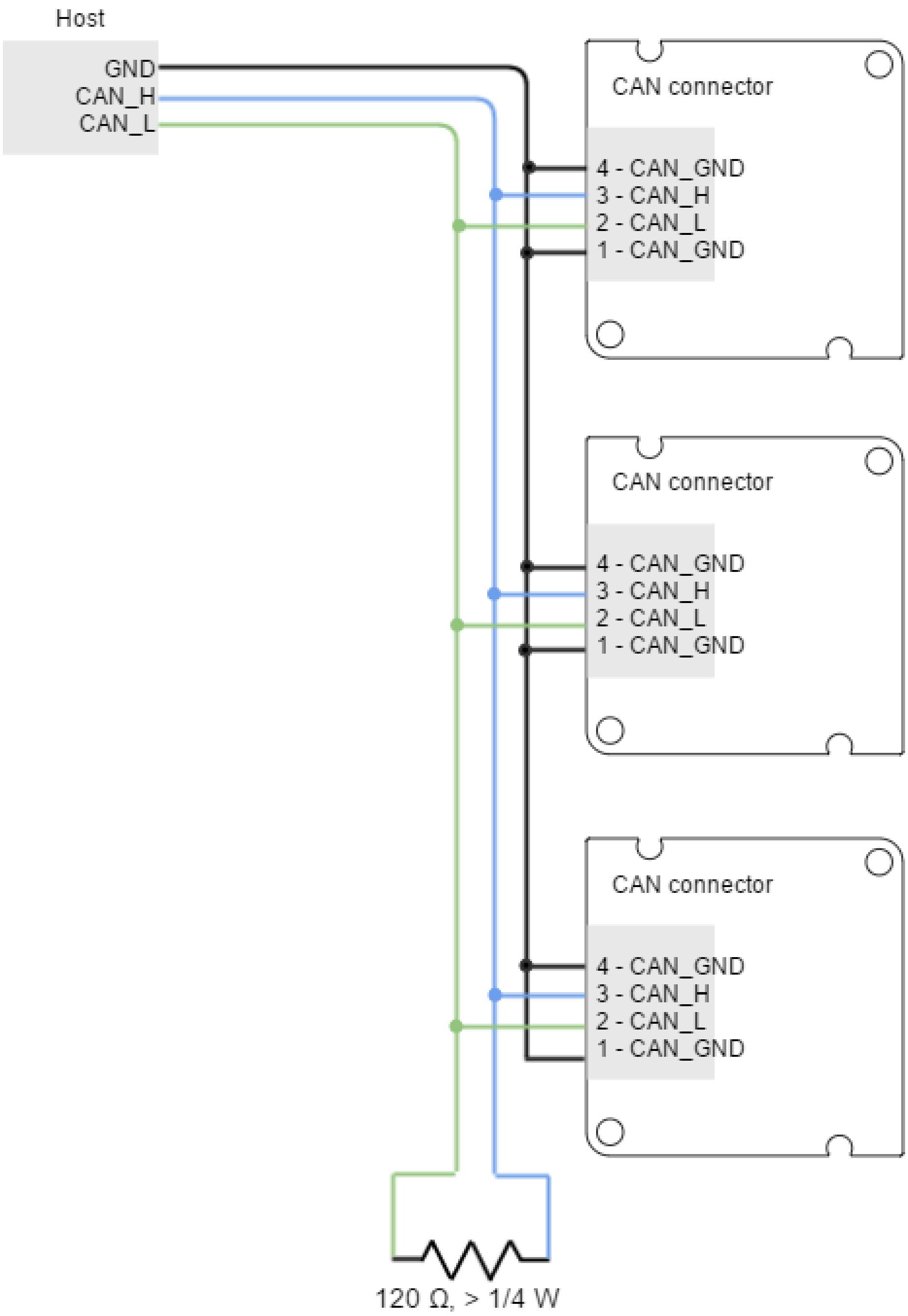
Neptune Servo Drive supports CANopen interface, a multi-terminal communication protocol based on CAN (Controller Area Network) bus. Neptune CAN interface is isolated, and self-supplied. Main physical specifications are shown in the next table:

Specification	**Details**
Interface	Non-isolated Self-supplied (no need for external supply)
Baud rate	From 125 kbps to 1 Mbps (default value)
Maximum number of nodes	64
Common mode voltage	Up to 48 V
Termination resistor	Not included on board

Drive ID

When installing CANopen communication, ensure that each servo drive is allocated a unique ID. Otherwise, CANopen network may hang.

An example of CAN wiring is shown in the next figure.



Termination resistor

The use of bus termination resistors (120 Ω between CAN_L and CAN_H), one at each end of the bus, is essential for correct operation of the CAN bus. Even with only one Neptune connected, mount the termination resistor to ensure CAN bus operation. **Do not use wirewound resistors**, which are inductive.

> **CAN GND connection**
>
> GND line in CAN devices is used for equaling potential between master and slaves, but is not used for data transmission, as the line is fully differential. For this reason, if the **host device shares supply GND with Nix it is not needed to connect CAN connector GND again**, as this could cause ground loop issues.
>
> If power supplies are isolated and flat ribbon cable is used, it is preferred to connect both GND connector pins (1 and 4), equaling the signal to GND impedance.

7.7.3.1 CAN interface for PC

The Ingenia Motion Lab suite is able to communicate with the Neptune Servo Drive through CANopen interface. For this purpose, a CAN transceiver for PC is required. Motion Lab is compatible with the following CAN transceivers: Kvaser, Peak-System, IXXAT, Vector and Lawicel. **Please, install the drivers you can find on the manufacturer web sites before, plugging any transceiver to the USB port. Execute Motion Lab only after the device is already installed.**

Some recommended CAN transceivers are shown below:

Manufacturer	Part Number	Image	Description
Peak-system	PCAN-USB opto-decoupled (IPEH-002022)		• USB to CAN single channel interface with 9-pin D-SUB CAN connector. • Enables simple connection to CAN networks. • Opto-decoupled with galvanic isolation of up to 500 Volts between the PC and the CAN side.
Kvaser	USBcan Pro 2xHS v2		• USB to CAN or CAN FD dual channel interface. • High-speed CAN channels in two separate 9-pin D-SUB CAN connectors.
IXXAT	USB-to-CAN V2 Professional		• USB to CAN dual channel interface. • High-speed CAN channels in two separate RJ-45 connectors. • Cable adapter to 9-pin D-SUB CAN.
Vector Informatik	VN1630		• USB to CAN or CAN FD four channel (two connectors) interface . • High-speed CAN channels in two separate 9-pin D-SUB CAN connectors. • Highly robust plastic housing.

7.7.3.2 CAN wiring recommendations

- Build CAN network using cables with **2-pairs of twisted wires** (2 wires/pair) as follows: one pair for CAN_H with CAN_L and the other pair for CAN_V+ with CAN_GND.
- Cable impedance must have an impedance of 105 to 135 Ω (120 Ω typical) and a capacitance below 30 pF/meter.
- Whenever possible, use bus links between the CAN nodes. **Avoid using stubs** (a "T" connection, where a derivation is taken from the main bus). If stubs cannot be avoided keep them as short as possible. For maximum speed (1 Mbps), use a stub length lower than 0.3 meters.
- For a total CAN bus length **over 40 meters**, it is mandatory to **use shielded twisted cables**. Connect the cable shield to protective earth at both ends. Ensure that the cable shield is connected to the connector shield, as connection to host protective earth is usually soldered inside the connector.

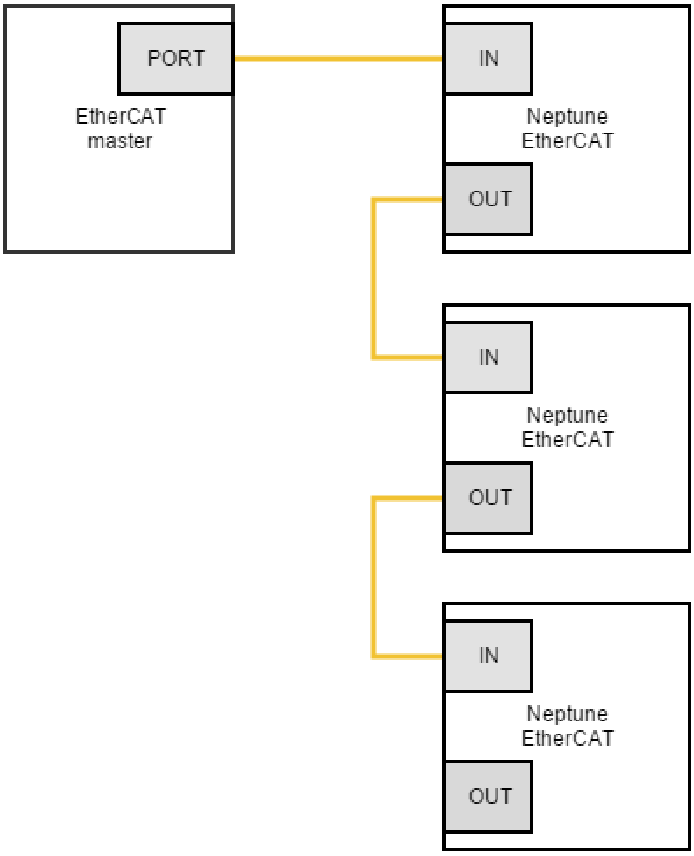
7.7.4 EtherCAT interface

Neptune Servo Drive with EtherCAT (NEP-x/xx-E-z) variant provides access to the EtherCAT fieldbus system. EtherCAT is an isolated bus suitable for hard and soft real-time requirements in automation technology, test and measurement and many other applications.

Next table summarizes the features of the Neptune EtherCAT interface.

EtherCAT specific features	
Ports available	2
LED Signals	Status LED
	Link/Act LED
Supported Mailbox	CoE
SDO info	Not supported
Segmented SDO	Supported
SDO complete access	Not supported
Synchronization modes	Free Run
	Distributed clock (*Cyclic modes)*
Process data object	Configurable, up to 64 objects

Next figure shows a wiring diagram of an EtherCAT bus.


PORT
EtherCAT
master
IN
Neptune
EtherCAT
OUT
IN
Neptune
EtherCAT
OUT
IN
Neptune
EtherCAT
OUT

8 Dimensions

The Neptune Servo Drive is available in 4 versions, each one with different specifications and dimensions:

- NEP-x/xx-y-S (Neptune with onboard connectors)
- NEP-x/xx-y-P (Neptune with gold plated pin headers)
- NEP-x/xx-E-S (Neptune with onboard connectors and EtherCAT)
- NEP-x/xx-E-P (Neptune with gold plated pin headers and EtherCAT)

Fixation elements diameter ≤ 6 mm

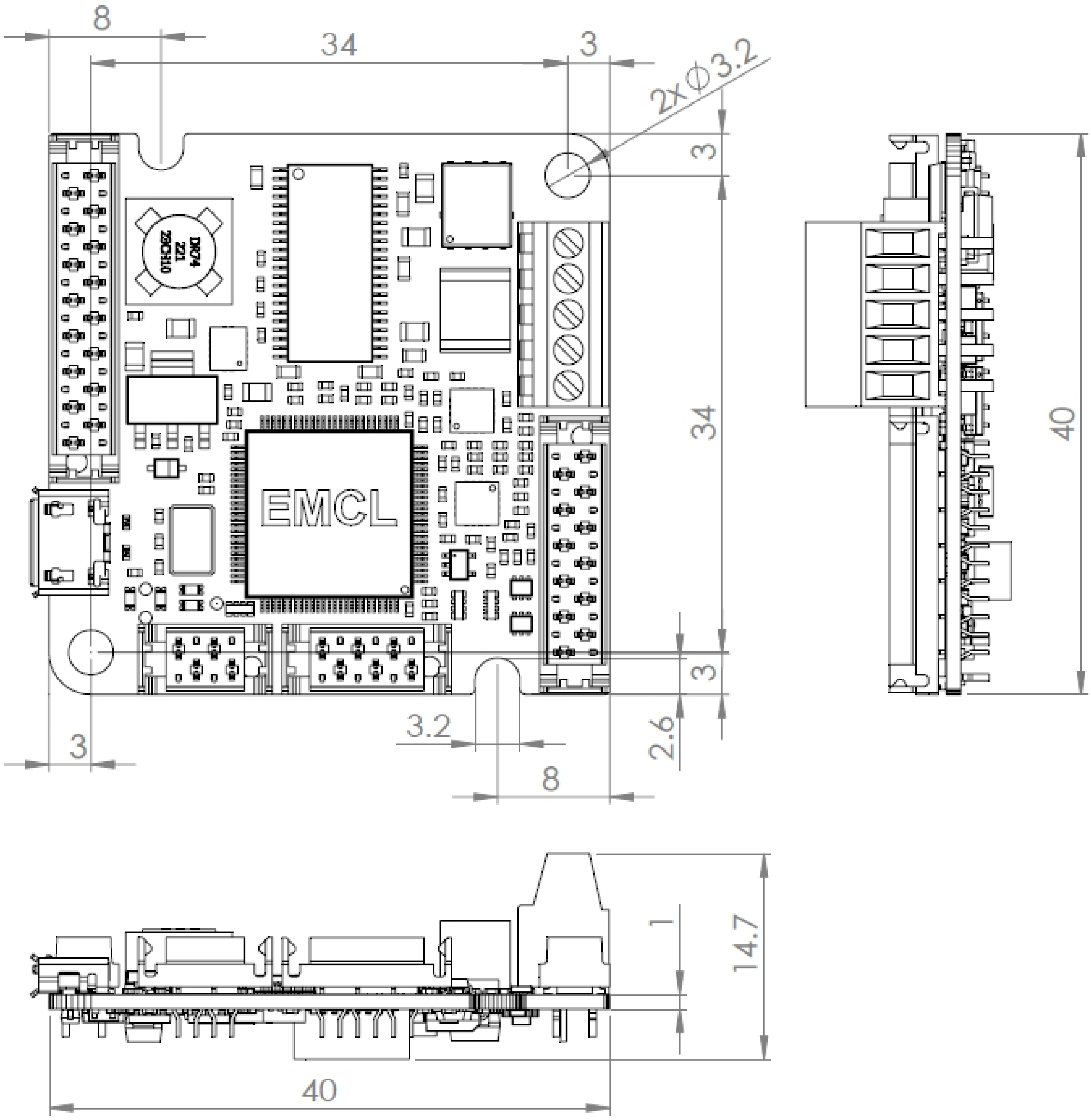
Please do not use spacers, washers or nuts exceeding 6 mm external diameter as they could collide with some electrical parts.

Also, take due precautions not to damage any components during assembly.

8.1 NEP-x/xx-y-S (Neptune with onboard connectors)

Neptune Servo Drive version NEP-x/xx-y-S has a 40 mm x 40 mm footprint and a maximum 14.7 mm height. The drive is provided with 2 x Ø 3.2 mm holes for M3 standoff mounting as well as 2 x 3.2 mm slots. Although 2 mounting holes could be sufficient in some cases, it is strongly recommended to use the 4 fixation points to provide better stability. 3D models can be downloaded here.

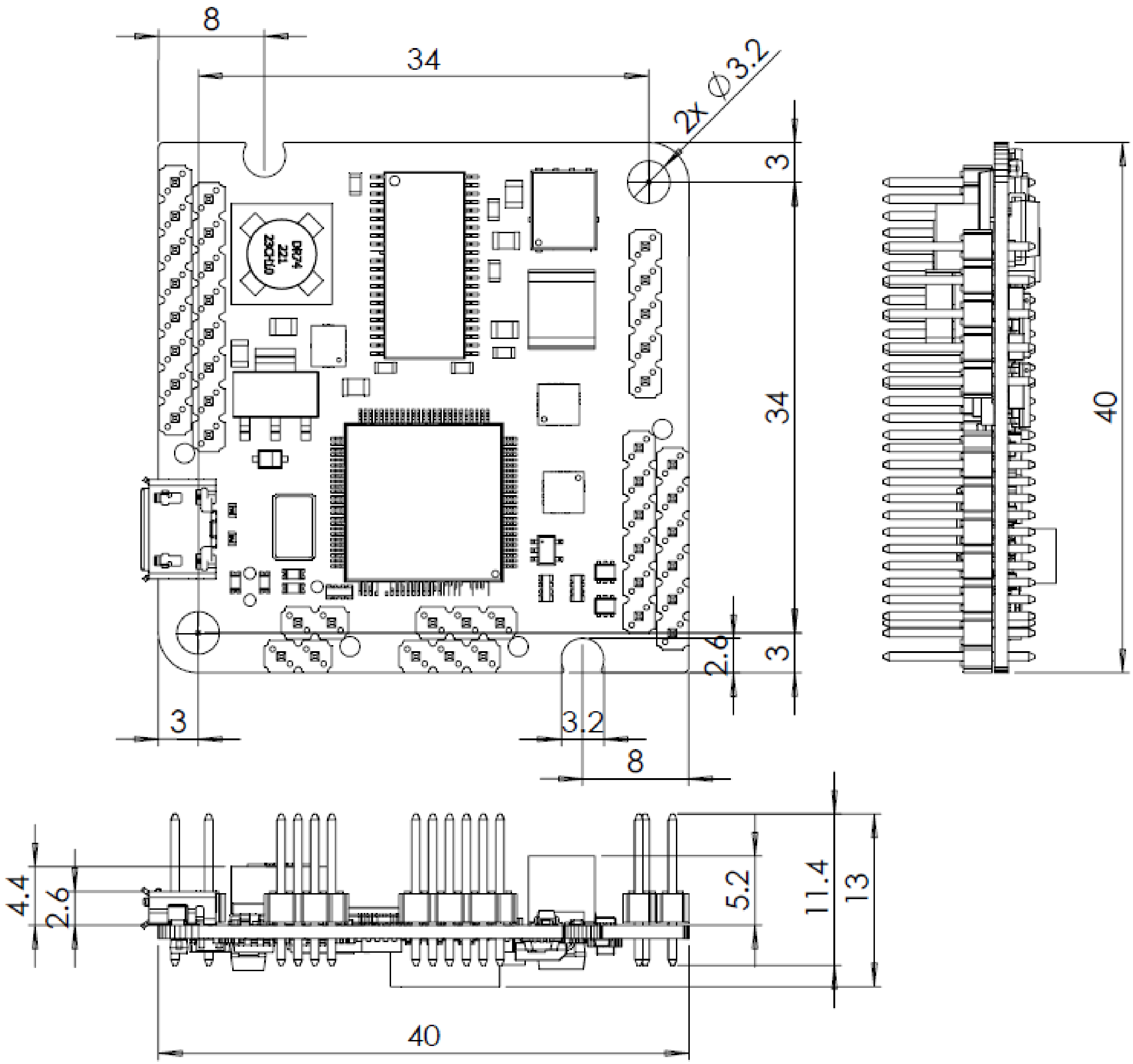
Next figure shows mechanical dimensions in **mm**. Tolerances **≤ ±0.2 mm.**



8.2 NEP-x/xx-y-P (Neptune with gold plated pin headers)

Neptune Servo Drive version NEP-x/xx-y-P has a 40 mm x 40 mm footprint and a maximum 13 mm height. The drive is provided with pin header connectors to allow the user to mount the Neptune in a custom board. 3D models can be downloaded here.

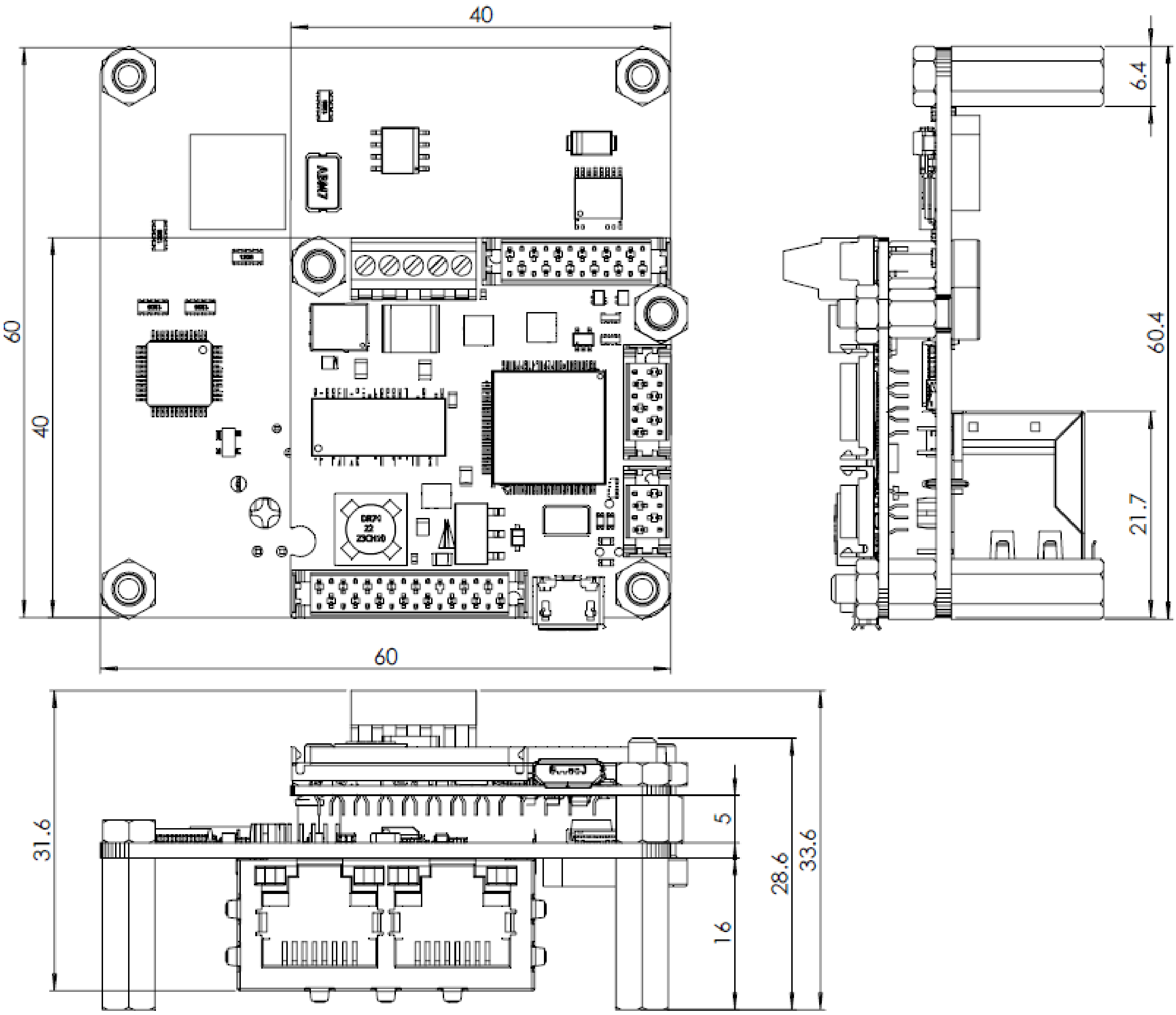
Next figure shows mechanical dimensions in **mm**. Tolerances **≤ ±0.2 mm.**



8.3 NEP-x/xx-E-S (Neptune with onboard connectors and EtherCAT)

Neptune Servo Drive version NEP-x/xx-E-S has a 60 mm x 60 mm footprint and a maximum 33.6 mm height. The drive is provided with 3 x M3 standoff of 6 mm to allow a proper mounting. 3D models can be downloaded here.

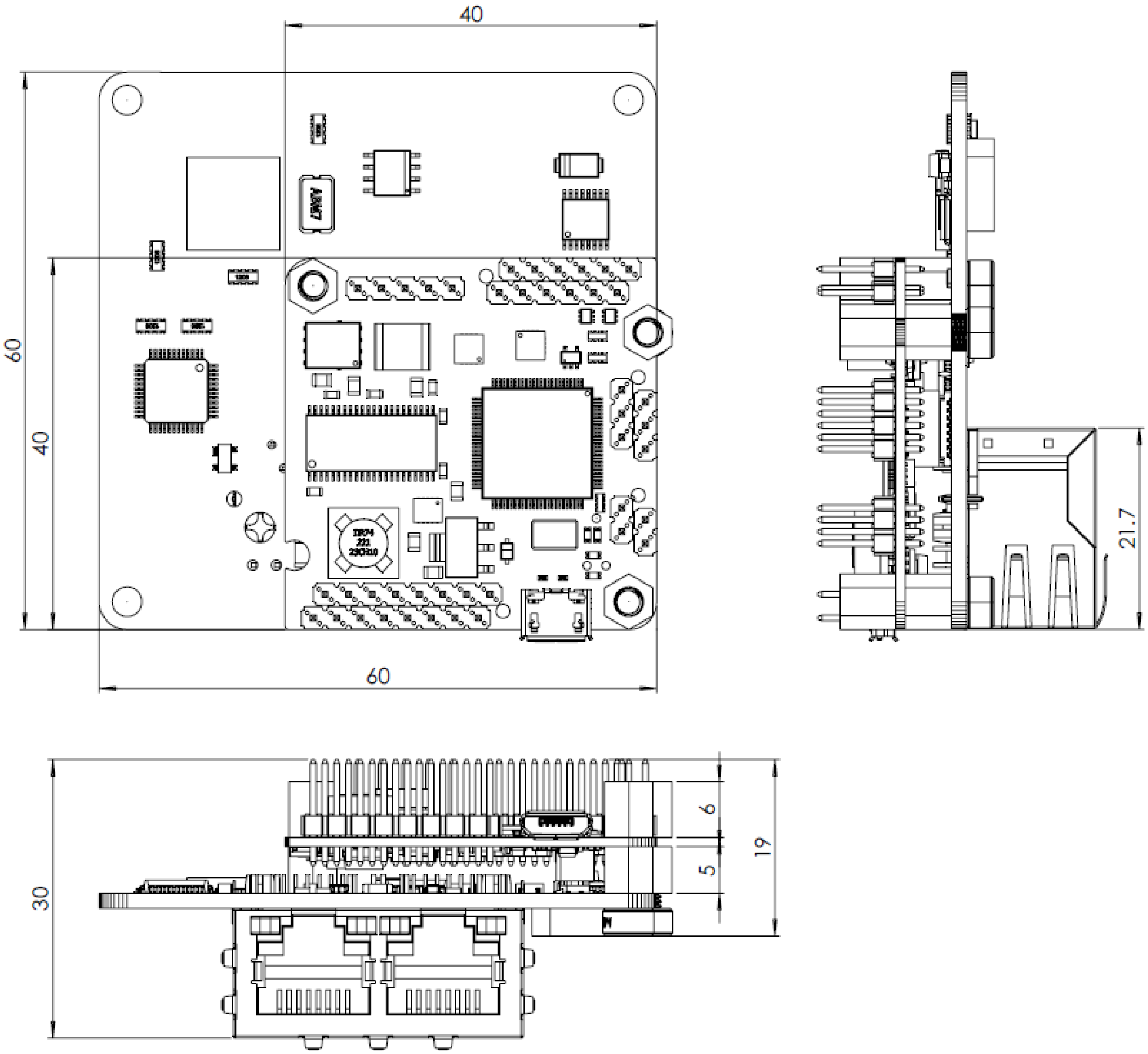
Next figure shows mechanical dimensions in **mm**. Tolerances **≤ ±0.2 mm.**



8.4 NEP-x/xx-y-P (Neptune with gold plated pin headers and EtherCAT)

Neptune Servo Drive version NEP-x/xx-y-S has a 60 mm x 60 mm footprint and a maximum 30 mm height. The drive is provided with 3 x M3 standoff of 6 mm to allow a proper mounting. 3D models can be downloaded here.

Next figure shows mechanical dimensions in **mm**. Tolerances **≤ ±0.2 mm.**


40
60
40
60
21.7
6
5
19
30

9 Software

9.1 Configuration

To connect, configure, tune your motor or upgrade the firmware of the Neptune, install Ingenia Motion Lab suite. The software package includes USB drivers.

> **Keep the firmware updated**
>
> Before configuring your drive for a new application make sure you have upgraded to the latest firmware revision.

9.2 Applications

If you want to make your own application to communicate with the Neptune and develop standalone or multiaxis systems, you can use the multi-platform library MCLIB**.**

9.3 Arduino

To start an Arduino based project easily, connect using the serial RS232 port of the Neptune and use our Arduino Library Ardulib**.**

Please make sure that your Arduino board has a RS232 port, or that a suitable adaptor is used.

10 Service

We are committed to quality customer service. In order to serve in the most effective way, please open a ticket on our service desk at www.ingeniamc.com/support or contact your local sales representative for assistance.

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