INGENIA

Hydra Servo Drive
Product Manual

Version: 4
Date: 03-Mar-2017

Table of Contents

1 General Information

1.1 Manual revision history

Revision	Release Date	Changes	PDF
v1	December 2015	Initial version	--
v2	April 2016	Added EtherCAT information. Structure improvements.	Download
v3	November 2016	Minor improvements	Download
v4	March 2017	Aesthetics and structure improvements. Wiring information improved.	--

For the most up to date information use the online Product Manual. The PDF manual is generated only after major changes.

Please refer to Hardware revisions for information on previous hardware revisions and changes.

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2 Safety Information

2.1 About this manual

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

To ensure maximum safety in operating the Hydra 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 Hydra Servo Drive, as well as other hardware that may be connected to it. Please read this chapter carefully before starting the installation process. Please also make sure all system components are properly grounded.

2.2 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 Hydra Servo Drive while the power supply is on.
- Power cables may be exposed to high voltages, even when the motor is not in motion. Disconnect the Hydra 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 1 minute before touching any parts of the controller that are electrically charged or hot (such as capacitors or contacts).

2.3 Precautions

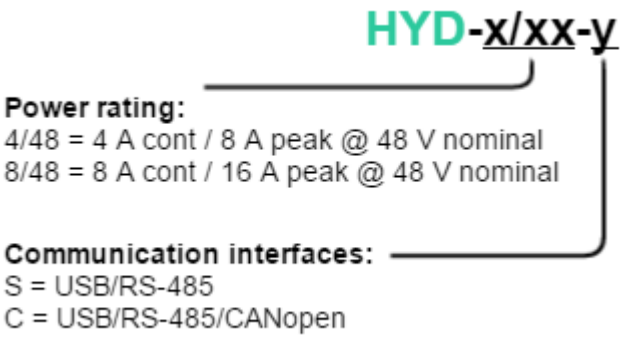
The following statements should be considered to avoid serious injury to those individuals performing the procedures and /or damage to the equipment:

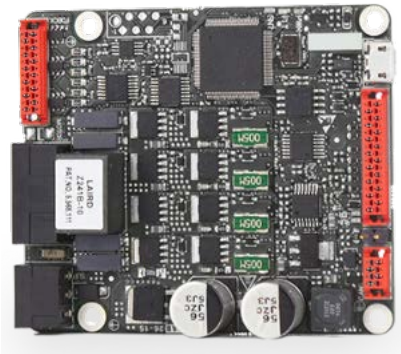
- The Hydra Servo Drive components temperature may exceed 100 ºC during operation.
- Some components become electrically charged when in operation.
- The power supply connected to this controller should comply with the parameters specified in this document.
- When connecting the Hydra Servo Drive to 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 Hydra Servo Drive, check that all safety precautions have been followed, as well as the installation procedures.

3 Product Description

Hydra is a high performance closed loop servo drive controller designed for two phase bipolar stepper motors. It can work in open and closed loop configurations.Designed for most demanding industrial, OEM, and scientific applications it is extremely rugged and has a low EMI profile. This makes it optimal for applications requiring long cables and for systems that demand low noise. Its design includes multiple communication ports RS485, USB and CANopen, enabling thus a wide choice of interfacing methods. Its extended voltage operating range 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 design also includes a wide variety of self and motor protection mechanisms.

3.1 Hydra part numbering



Ordering part number	Status	Image
HYD-4/48-S	ON DEMAND	
HYD-4/48-C	ON DEMAND	
HYD-8/48-S	ACTIVE	
HYD-8/48-C	ACTIVE	

3.2 Specifications

Electrical and power specifications		
Part number →	**HYD-4/48-y**	**HYD-8/48-y**
Power supply voltage	12 V_{DC} to 48 V_{DC}	
Transient peak voltage	60 V	
Logic supply voltage	Not needed, supplied from Power supply voltage	
Internal DC bus capacitance	112 µF	
Minimum motor inductance	300 µH	

Nominal phase continuous current	4 A_{RMS}	8 A_{RMS}
Maximum phase peak current	8 A_{RMS} (5 s)	16 A_{RMS} (5 s)
Current sense range	± 16 A	± 32 A
Current sense resolution	31.16 mA/count	62.32 mA/count
Shunt braking transistor	Shunt braking transistor on board. 16 A maximum current.	
Cold plate	No	
Power connectors	Pluggable terminal	
Standby power consumption	1.5 W (max)	
Efficiency	> 97% at the rated power and current	
Motion control specifications		
Supported motor types	• 2 phases bipolar stepper	
Power stage PWM frequency	40 kHz (default) 80 kHz (alternative PWM frequency, configurable)	
Current sensing	On phases A, B and C using 3 terminal shunt resistors. Accuracy is ± 1% full scale. 10 bit ADC resolution.	
Sensors for commutation	• Quad. Incremental encoder	
Sensors supported for servo loops	• Quad. Incremental encoder	
Supported target sources	• Network communication – USB • Network communication – CANopen • Network communication – RS-485 • Standalone (execution from Internal EEPROM memory) • Analog input (±10 V or 0 V 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, 24 V tolerant). • 2 x non isolated high speed differential digital inputs. HS_GPI1 Pulse, HS_GPI2 Direction (5 V logic, 24 V 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. (24 V tolerant and 1 A short-circuit and over-current 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-DC bus
	  • Phase-phase
	  • Phase-GND
	• Mechanical limits for homing functions
	• ESD protections in all inputs, outputs, feedbacks and communications.
	• EMI protections (noise filters) in all inputs, outputs, feedbacks and motor connections.
	• Inverse polarity supply protection (bidirectional)
	• High power transient voltage suppressor for short braking (1500 W peak TVS diode).
	• Encoder broken wire (for differential quadrature encoders only).

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.
Serial	RS485 full-duplex (compatible with RS422), non-isolated. 120Ω termination not included on board.
CANopen	Available. Non-isolated. Includes jumper to enable 120 Ω termination. CiA-301, CiA-305 and CiA-402 compliant.
EtherCAT	Not available.
Environmental and mechanical specifications	
Ambient air temperature	• -40 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	60 mm x 70 mm x 15.7 mm
Weight (exc. mating connectors)	35 g

3.3 Hardware revisions

Hardware revision*	Description and changes
1.0.0	First product release.

Identifying the hardware revision

Hardware revision is screen printed on the board.

3.4 Power and current ratings

Hydra is capable of providing the nominal current from -10ºC to 50ºC ambient air temperature without the need of any additional heatsink or forced cooling system. From 50ºC to 80ºC of ambient temperature a current derating is needed.

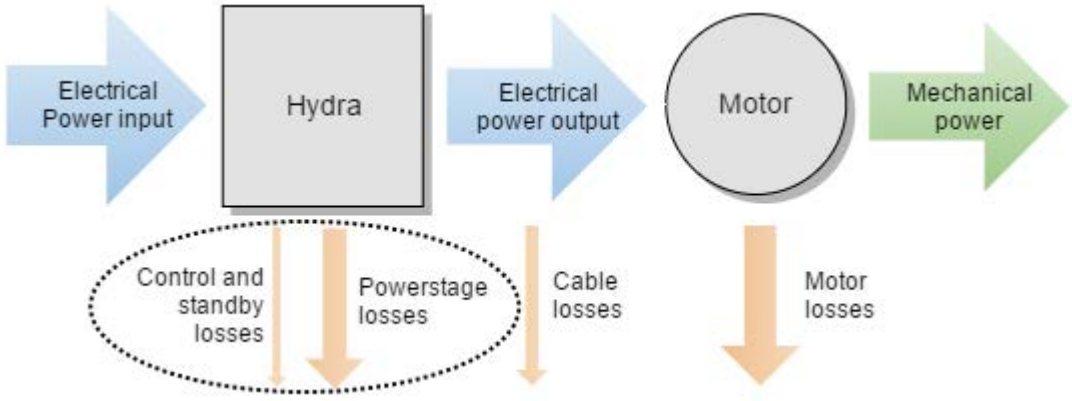
Excessive power losses lead to over temperature that will be detected and cause the drive to turn off. The system temperature is available in E-Core registers and is measured on the power stage. The temperature parameter that can be accessed from USB 2.0, CAN or RS485 interface does not indicate the air temperature. Above 110ºC the Hydra 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.

Current foldback based on temperature

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

Some parts of the Hydra exceed 110ºC when operating, especially at high load levels.
Do not touch the drive 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.



3.4.1 Power losses calculation (heat dissipation)

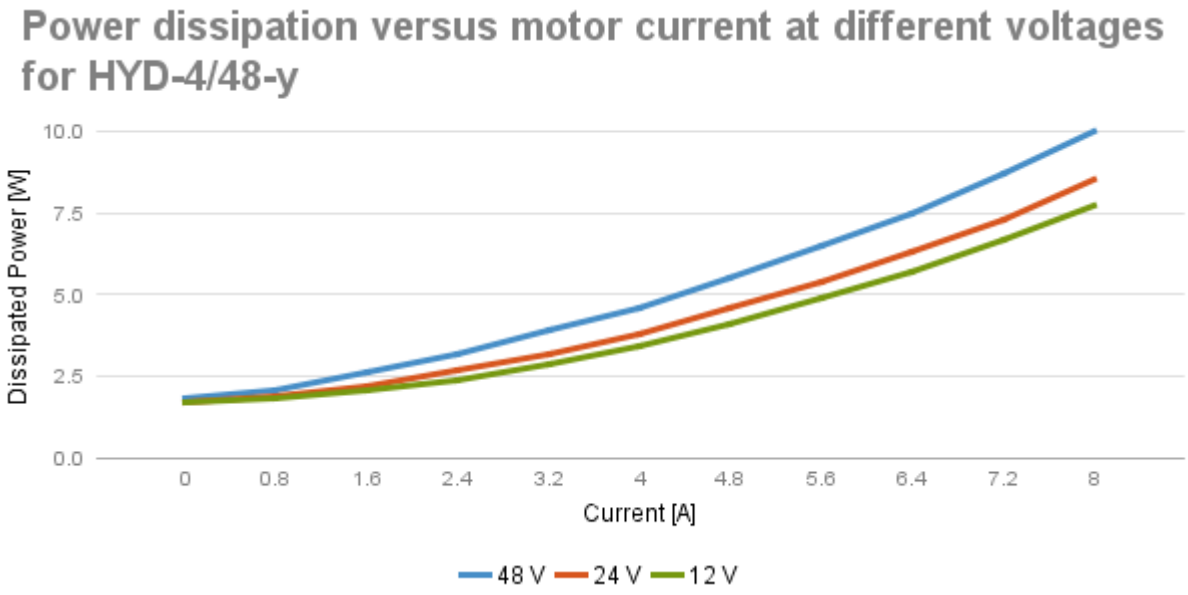
Operation of the Hydra causes power losses that should be transferred to the surrounding environment as heat. Heat dissipation depends on various parameters. Principally:

- **Motor RMS current**: positive correlation.
- **DC bus voltage**: positive correlation.

Other less relevant parameters affect also the power loss but are not considered in the graphs:

- Air temperature, higher power semiconductor temperatures reduce their efficiency.

- Motor speed. Faster motor speeds result in higher overall power loss since the input current is greater. This increases conduction losses on the reverse polarity protection circuitry.

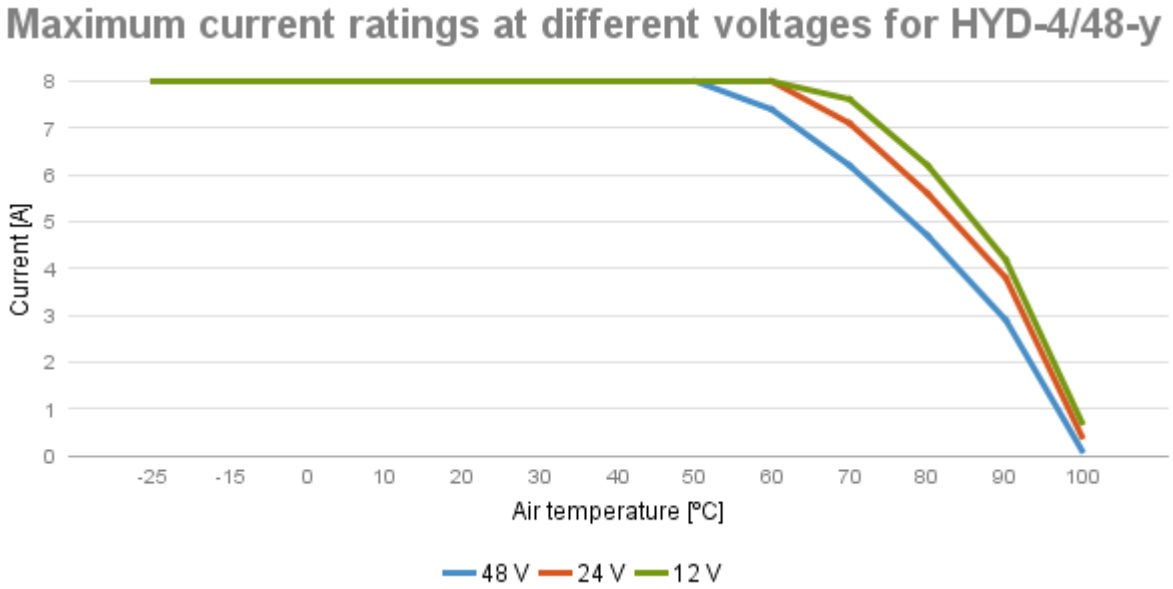


3.4.2 Current ratings

The Hydra 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, the output current must be limited to avoid an excessive drive temperature (T_P< 110ºC). The threshold temperature where the current derating should start depends on the DC bus voltage.



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.

3.4.3 Dynamic application (non-constant current)

The Hydra 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.

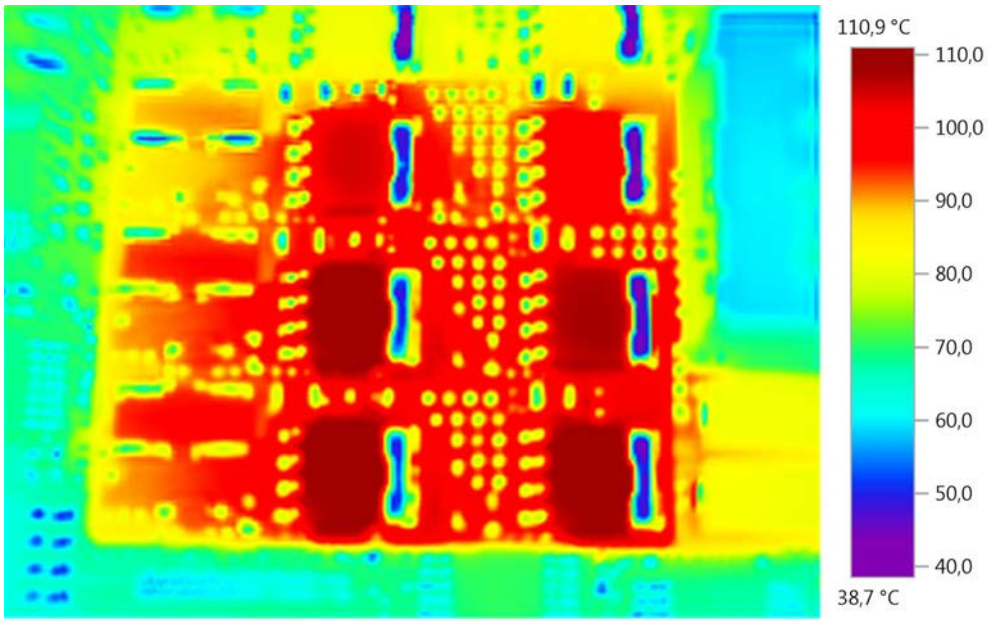
$\mathbf{I_1}$ is the current during t_1

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

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

3.4.4 System temperature

Next thermal image shows an example of the heat distribution in a HYD-8/48-y. The test has been performed at maximum load and air temperature.



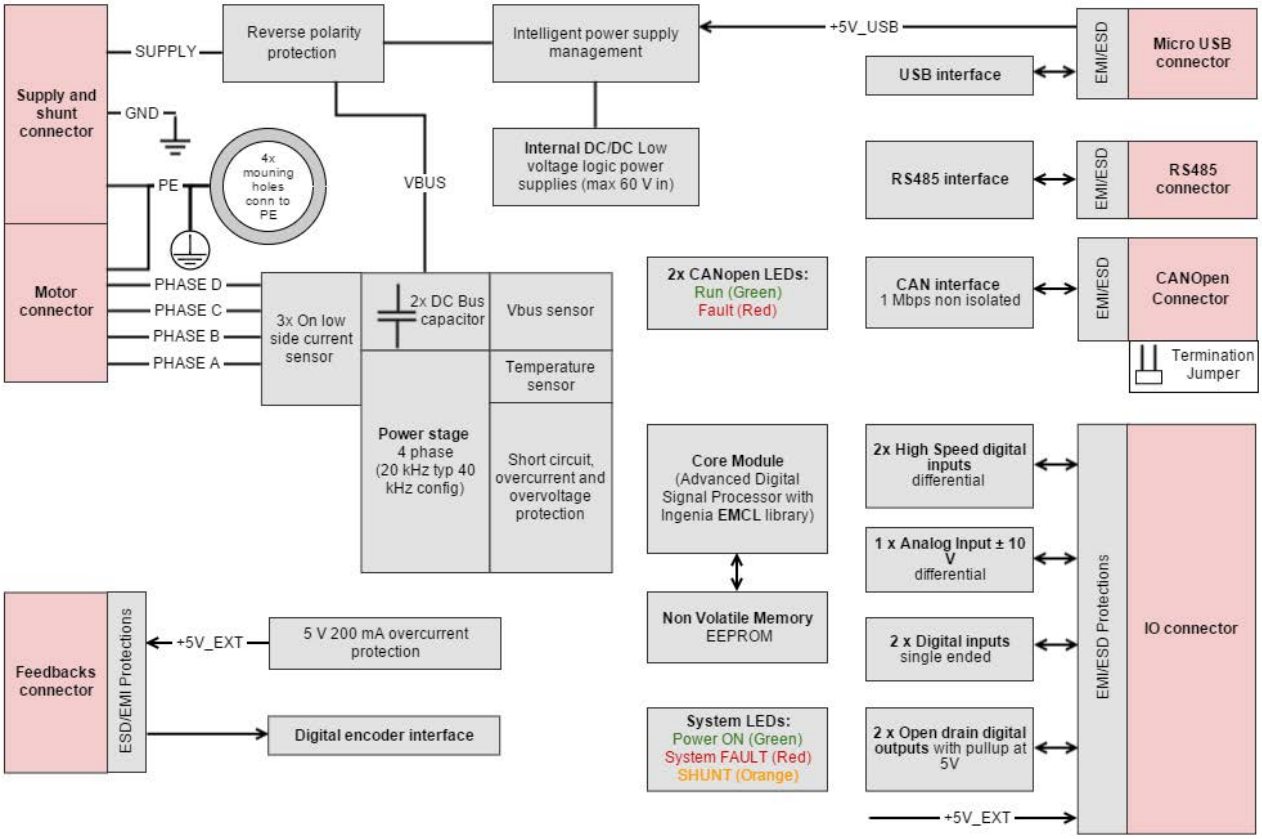
The drive is getting hot even at 0 current!

This is normal. Hydra 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.

3.5 Architecture

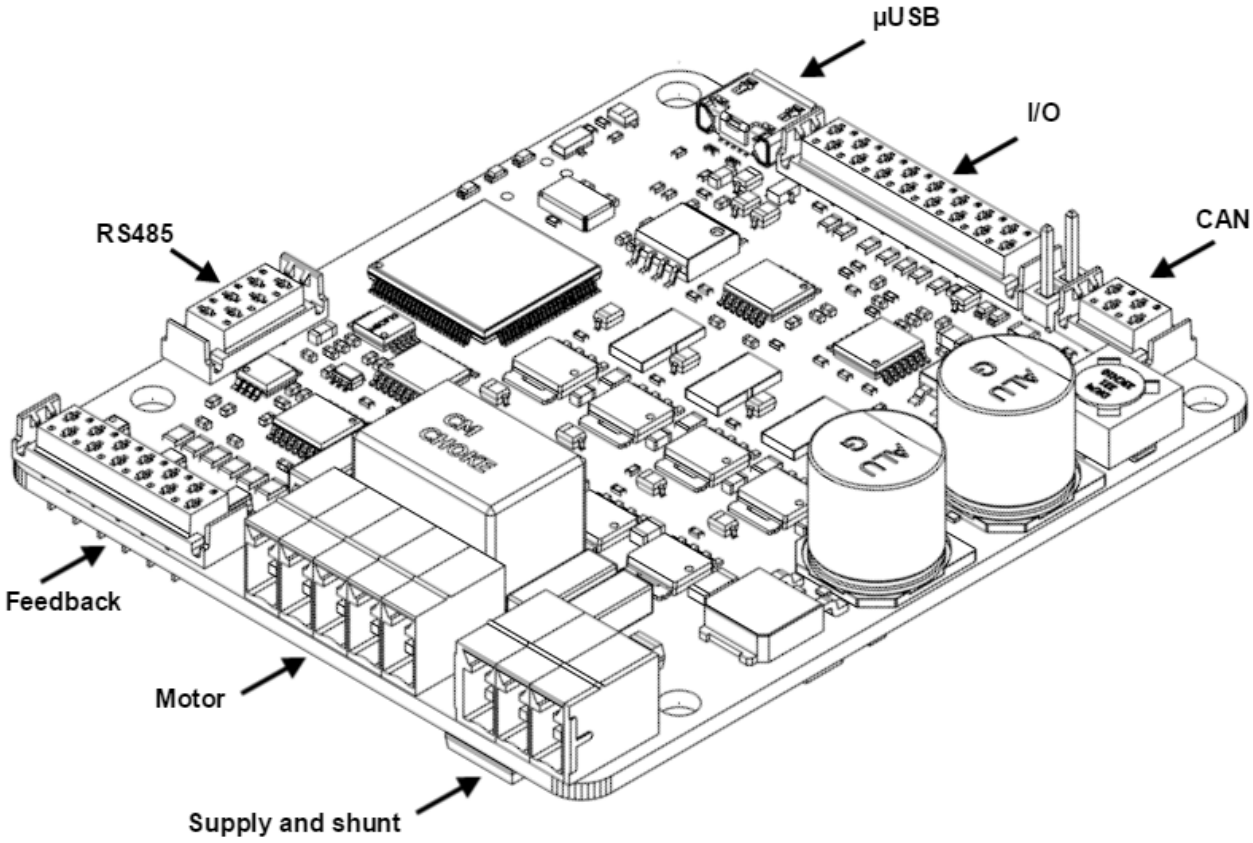
Following figure shows a simplified hardware architecture of the Hydra Servo Drive. Links provide direct access to relevant pages.

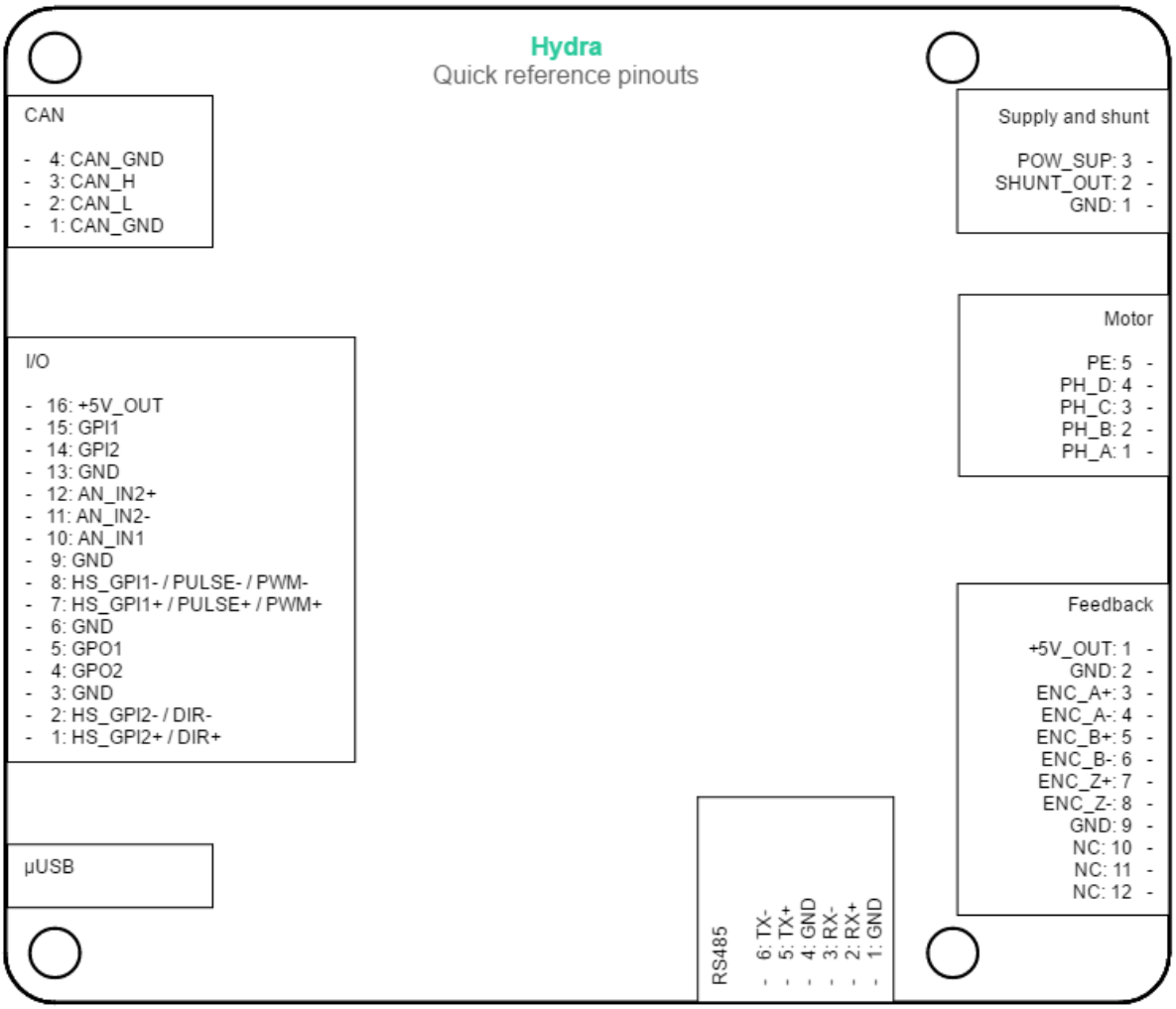


4 Connectors Guide

4.1 Connectors position and pinout

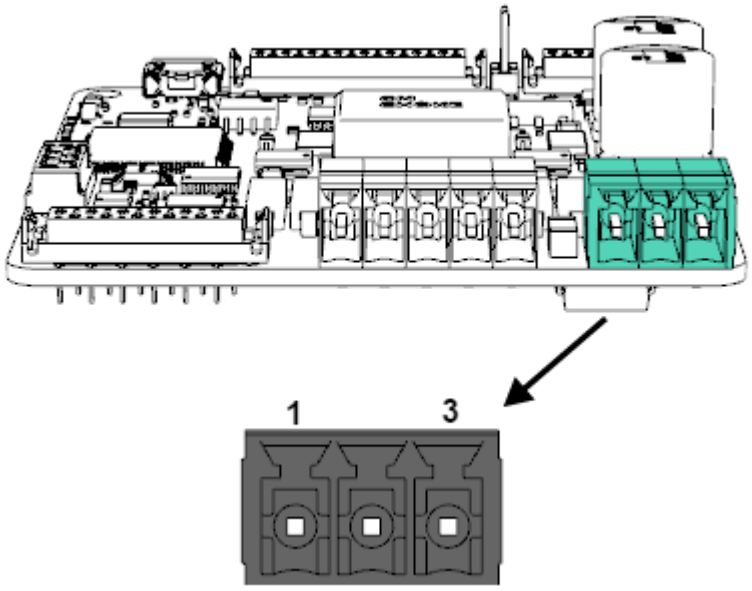
The Hydra Servo Drive presents the following connectors and pinout:




Hydra
Quick reference pinouts
CAN
- 4: CAN_GND
- 3: CAN_H
- 2: CAN_L
- 1: CAN_GND
Supply and shunt
POW_SUP: 3 -
SHUNT_OUT: 2 -
GND: 1 -
Motor
PE: 5 -
PH_D: 4 -
PH_C: 3 -
PH_B: 2 -
PH_A: 1 -
I/O
- 16: +5V_OUT
- 15: GPI1
- 14: GPI2
- 13: GND
- 12: AN_IN2+
- 11: AN_IN2-
- 10: AN_IN1
- 9: GND
- 8: HS_GPI1- / PULSE- / PWM-
- 7: HS_GPI1+ / PULSE+ / PWM+
- 6: GND
- 5: GPO1
- 4: GPO2
- 3: GND
- 2: HS_GPI2- / DIR-
- 1: HS_GPI2+ / DIR+
Feedback
+5V_OUT: 1 -
GND: 2 -
ENC_A+: 3 -
ENC_A-: 4 -
ENC_B+: 5 -
ENC_B-: 6 -
ENC_Z+: 7 -
ENC_Z-: 8 -
GND: 9 -
NC: 10 -
NC: 11 -
NC: 12 -
µUSB
RS485
- 6: TX-
- 5: TX+
- 4: GND
- 3: RX-
- 2: RX+
- 1: GND

4.2 Supply and shunt connector

P1 Connector



3 position 3.5 mm pitch pluggable terminal block. FCI 20020110-C031A01LF.

Pin	Signal	Function
1	GND	Ground connection
2	SHUNT_OUT	Shunt braking transistor output
3	POW_SUP	Power supply input

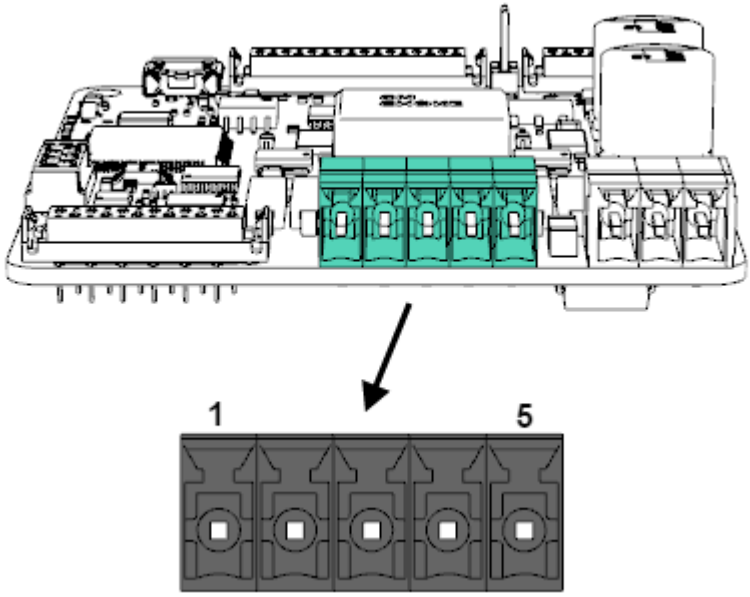
Mating	
Description	Pluggable terminal block, 3 positions 3.5 mm pitch
Part number	Phoenix Contact 1840379
Distributor codes	Farnell 5088963 Digi-Key 277-2413-ND Mouser 651-1840379

Notes

- See Power supply wiring for power wiring information.
- For details on shunt operation see Motor and shunt braking resistor.
- Dimension the wiring according to the application current ratings. Higher section is always preferred to minimize resistance and wire self-heating. Recommended wire section is 0.5 mm² ~ 1.5 mm².

4.3 Motor connector

P2 Connector



5 position 3.5 mm pitch pluggable terminal block. FCI 20020110-C051A01LF.

Pin	Signal	Function
1	PH_A	Motor phase A connection
2	PH_B	Motor phase B connection
3	PH_C	Motor phase C connection
4	PH_D	Motor phase D connection
5	PE	Motor protective earth connection, internally connected to supply PE and standoffs

Mating	
Description	Pluggable terminal block, 5 positions 3.5 mm pitch
Part number	Phoenix Contact 1840395
Distributor codes	Farnell 5088987 Digi-Key 277-5721-ND Mouser 651-1840395

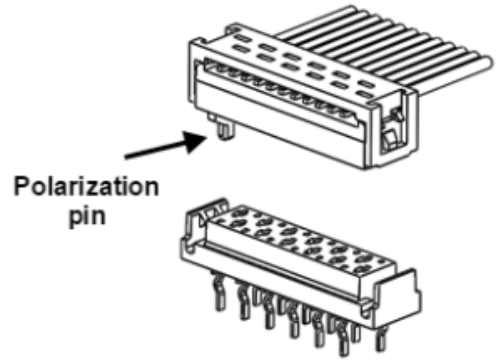
Notes

- Dimension the wiring according to the application current ratings. Higher section is always preferred to minimize resistance and wire self-heating. Recommended wire section is 0.5 mm² ~ 1.5 mm²
- For wiring information, see motor and shunt braking resistor and protective earth wiring sections.

4.4 Micro-Match connectors mating

Most Hydra 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**.

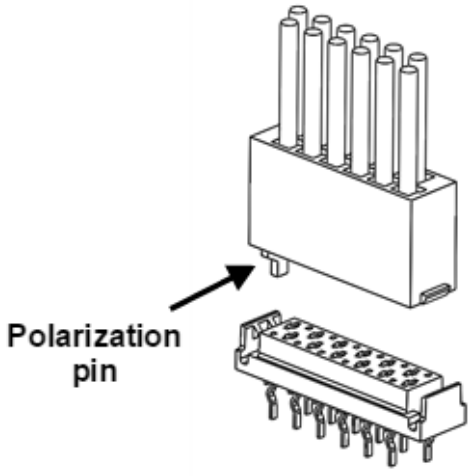
4.4.1 Ribbon cable

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.

4.4.2 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

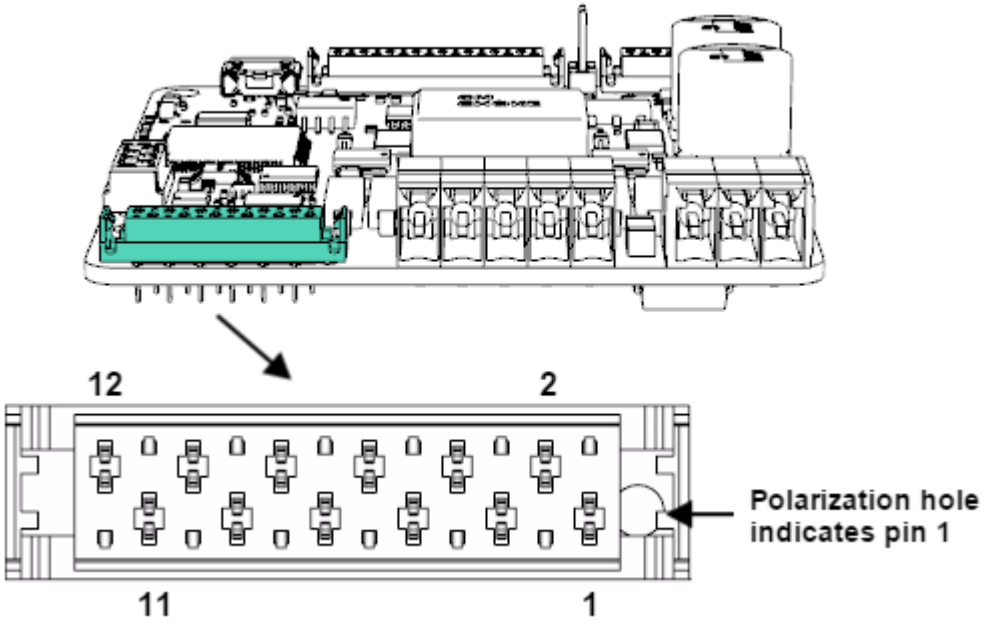
Crimped single cables makes wiring cleaner and is a preferred option for volume applications.

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**.

4.5 Feedback connector

P3 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	NC	Not connected
11	NC	Not connected
12	NC	Not connected

Notes

- Polarization hole on PCB indicates pin 1 and ensures correct cable position.
- See Feedback connections for further information about different feedbacks wiring.
- Hydra 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 Neptune 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

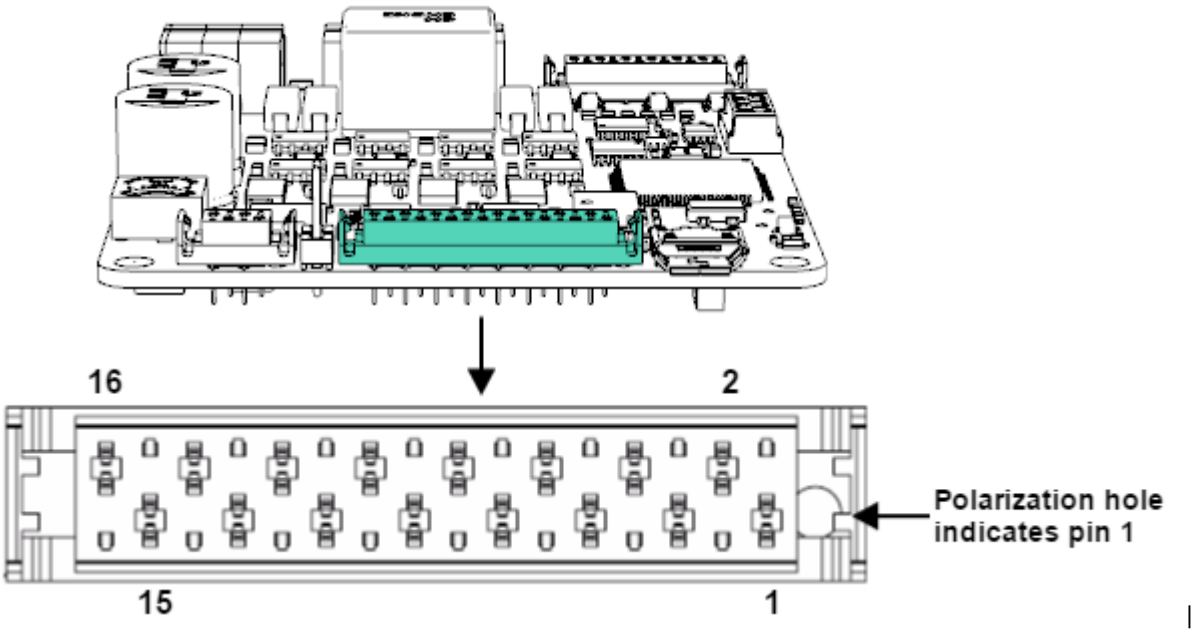
Notes

- 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.	

4.6 I/O connector

P4 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
8	HS_GPI1- / PULSE- / PWM-	High speed digital differential input 1- Command source: Pulse- 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 under 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.
- Hydra 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 Neptune 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

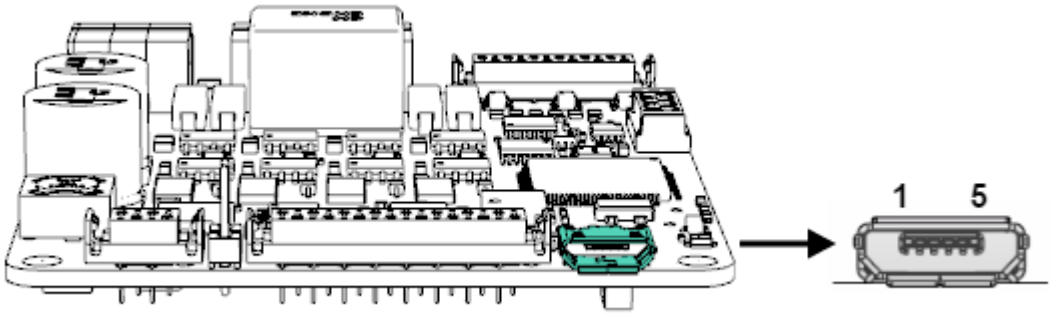
Notes

- 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 mm² (20 ~24 AWG) flexible wires.	

4.7 USB connector

P5 Connector

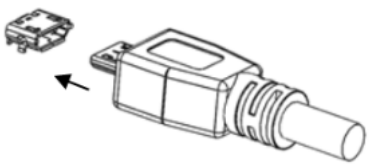


5 pin horizontal micro-USB connector Amphenol FCI 10118193

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.

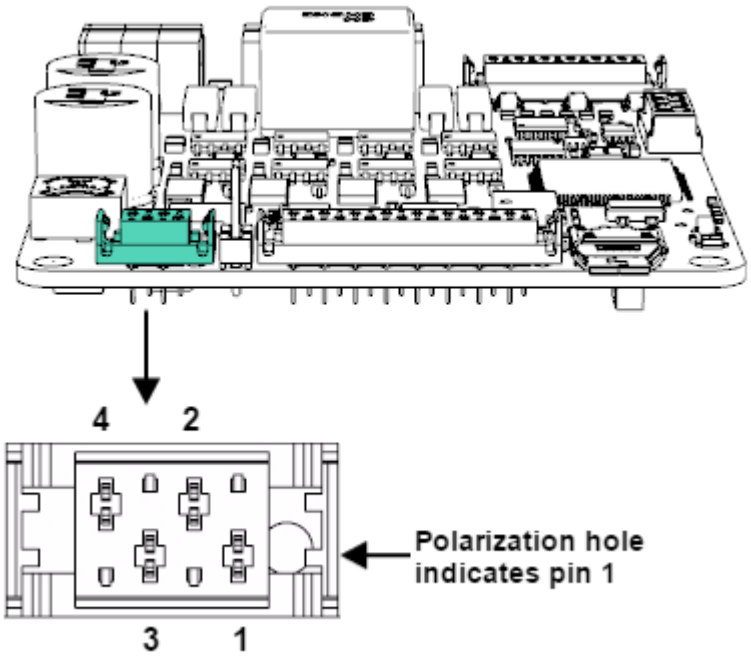
Notes

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

4.8 CAN connector

P6 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 page for further information about CAN wiring.
- Hydra 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.

4.8.1 Cleverly wiring CAN buses from standard DB9 connectors

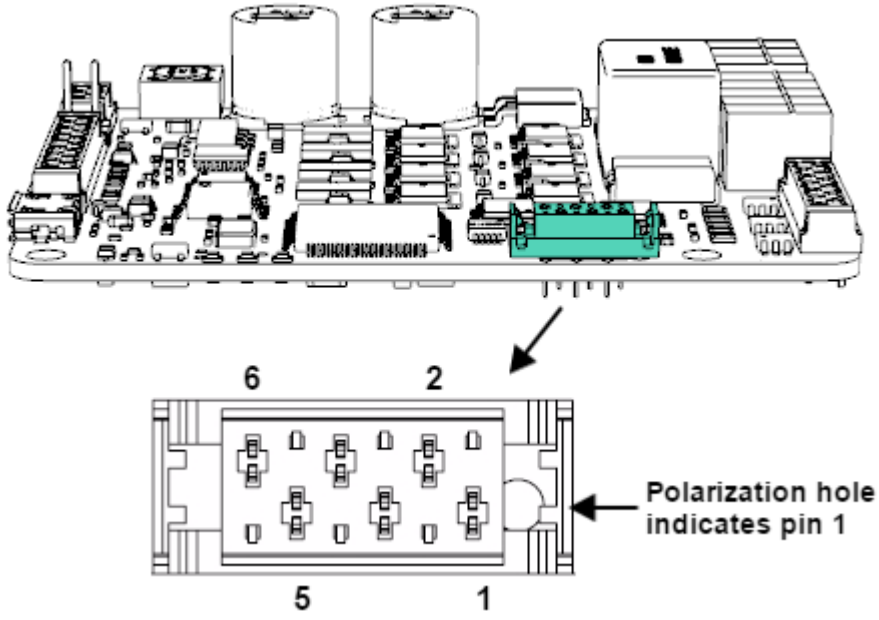
The Hydra CAN pinout allows an easy connection to the standard DB9 connector using a 4 way 1.27 pitch flat ribbon cable.
Use a DB9 to ribbon connector like: H7MXH-0906M-ND or AMPHENOL L117DEFRA09S-ND. Corresponding pinouts:

Hydra 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)

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 mm² (20 ~24 AWG) twisted pair with 120 Ω differential impedance.	

4.9 RS485 interface connector

P7 Connector



6 pin TE Micro-Match 338068-6 connector.

Pin	Signal	Function
1	GND	Common (internally connected to drive GND)
2	RX+	RS485 receive data + (should be connected to master TX+)
3	RX-	RS485 receive data - (should be connected to master TX-)
4	GND	Common (internally connected to drive GND)
5	TX+	RS485 transmit data + (should be connected to master RX+)
6	TX-	RS485 transmit data - (should be connected to master RX-)

Notes

- Polarization hole on PCB indicates pin 1 and ensures correct mating connector position.
- See Communications for further information about RS485 wiring.
- Hydra connectors include locking latches that provide audible click during mating and ensure assembly robustness

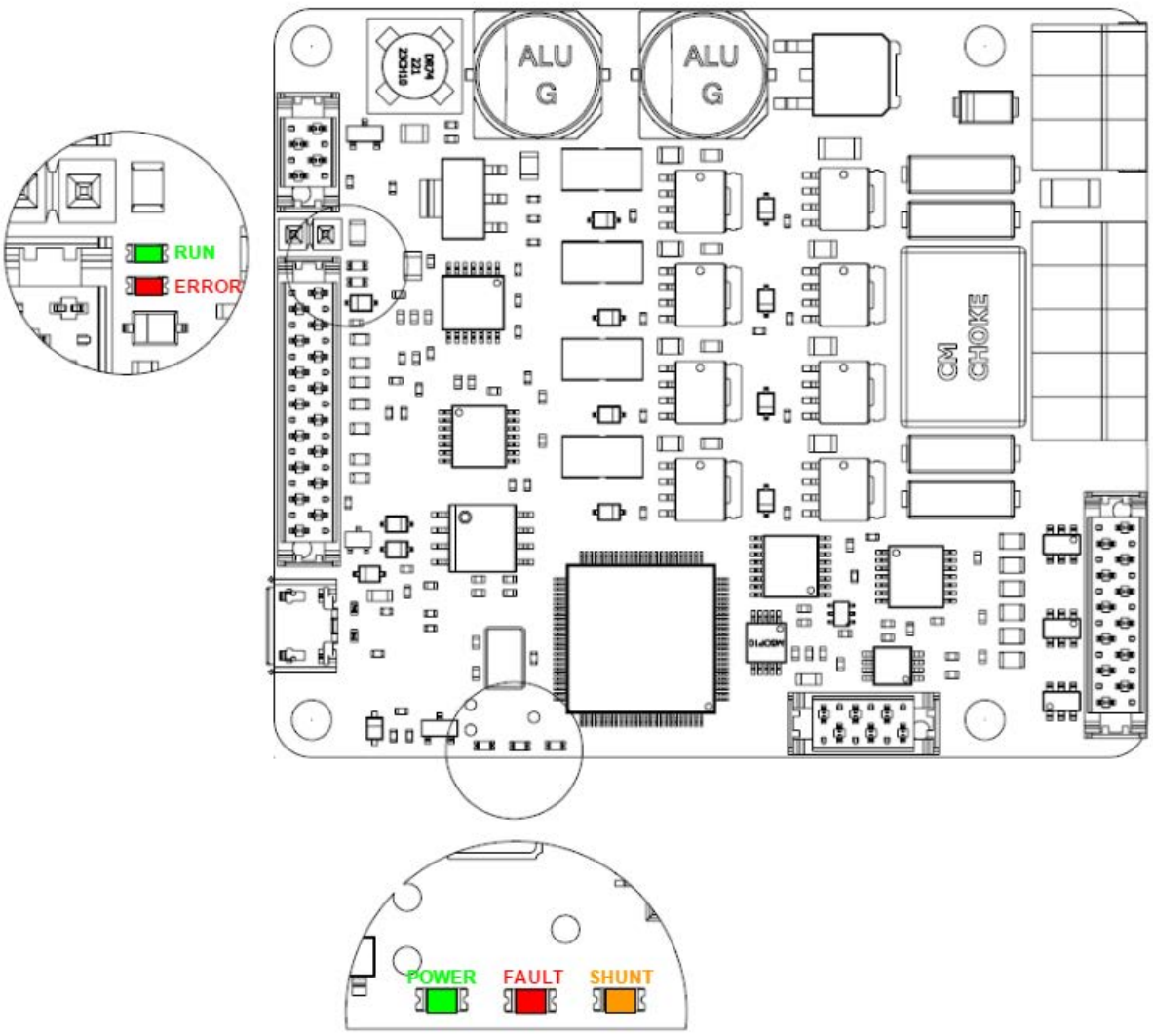
Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch 6 position
Part number	TE Connectivity 215083-6
Distributor codes	Digi-Key A99463CT-ND Mouser 571-7-215083-6
Cable	
Part number	3M HF365/06SF
Distributor codes	Farnell 1859550 Digi-Key MD06R-100-ND Mouser 517-HF365/06SF

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 mm² (20 ~24 AWG) flexible cable.	

5 Signalling LEDs

Hydra Servo Drive provides information through 5 signalling LEDs:

- Supply and operation: 3 LEDs next to the DSP, between the USB and RS485 connectors.
- CANopen communication: 2 LEDs next to the CAN and I/O connectors.



5.1 Power and operation signalling LEDs

Three LEDs situated next to the DSP, between the USB and RS485 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.

SHUNT	Orange	LED is turned on with the shunt braking resistor is activated, indicating that maximum user voltage has been exceeded and power is being dissipated.

5.2 CAN signalling LEDs

Two LEDs besides the CAN and I/O 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
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 Wiring and Connections

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

6.1 Protective earth

Connection of Hydra 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.

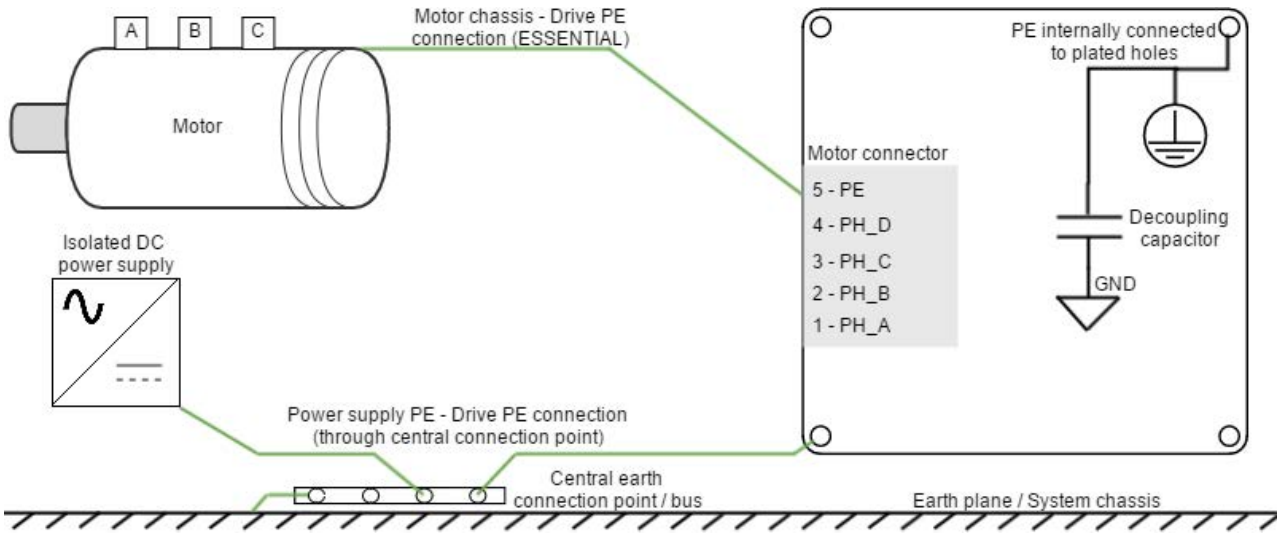
Moreover, a proper connection to PE prevents many of the noise problems that occur operating a servo drive.

> **Reducing EMI susceptibility**
>
> **Connecting the drive PE terminals** and cold plate screws **to your system Earth and to the motor housing solves many noise and EMI problems.** The PE drive terminals are decoupled to power ground through a safety capacitor. This 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.

Hydra Servo Drive provides the following earth/ground connection points, which are internally connected and decoupled to power ground:

- PE terminal in the Motor connector.
- Plated holes for standoffs.

A diagram of the recommended Earth wiring is shown following.



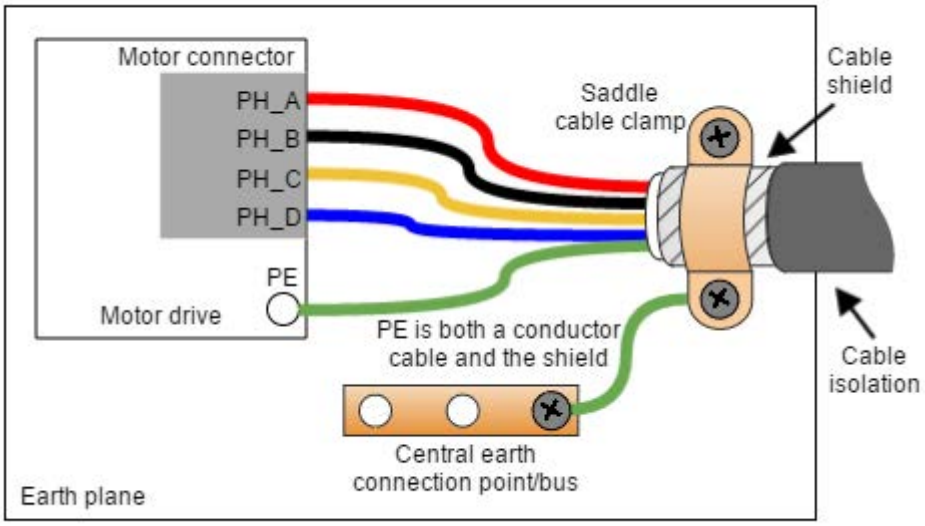
Earth plane reference

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 Hydra 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

6.2 Power supply

The Hydra Servo Drive is supplied from the Supply and shunt connector, using the same terminal for logic and power supply (12 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 Hydra 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 Hydra

When the Hydra 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 Hydra. 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.

6.2.1 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 Hydra power supply are:

- The **voltage** should be the targeted for the motor. This means up to **48 V** for the **HYDRA-8/48**. 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 **8 A** for the **HYDRA-4/48** and up to **16 A** for the **HYDRA-8/48.** 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	PFE500F48	48	10.5		Switching closed frame power supply, 500 W
TDK Lambda	PFE1000F48	48	21		Switching closed frame power supply, 1000 W

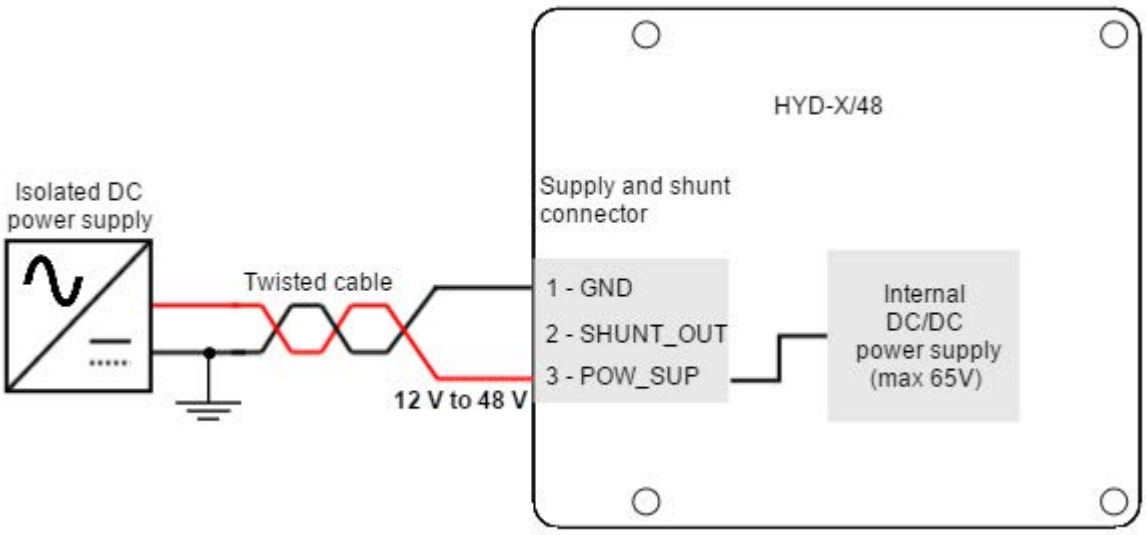
6.2.2 Power supply connection

Hydra logic and power supply are provided through the same terminal. All Hydra versions support an input voltage of +12 V to +48 V.

Twisted cables

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

The following picture show the Hydra supply wiring diagram.

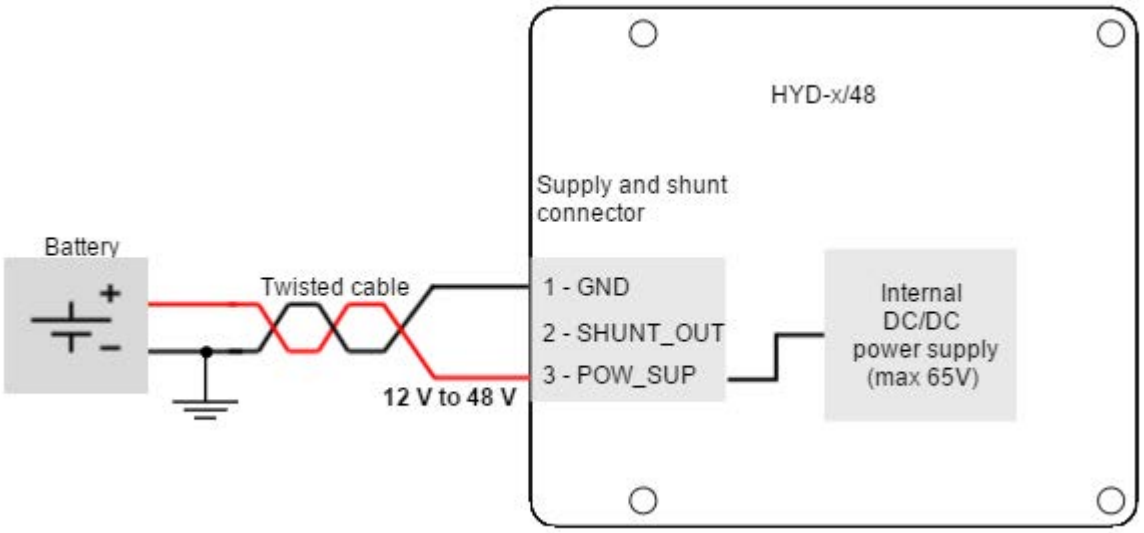


Isolated power supplies

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

6.2.3 Battery supply connection

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



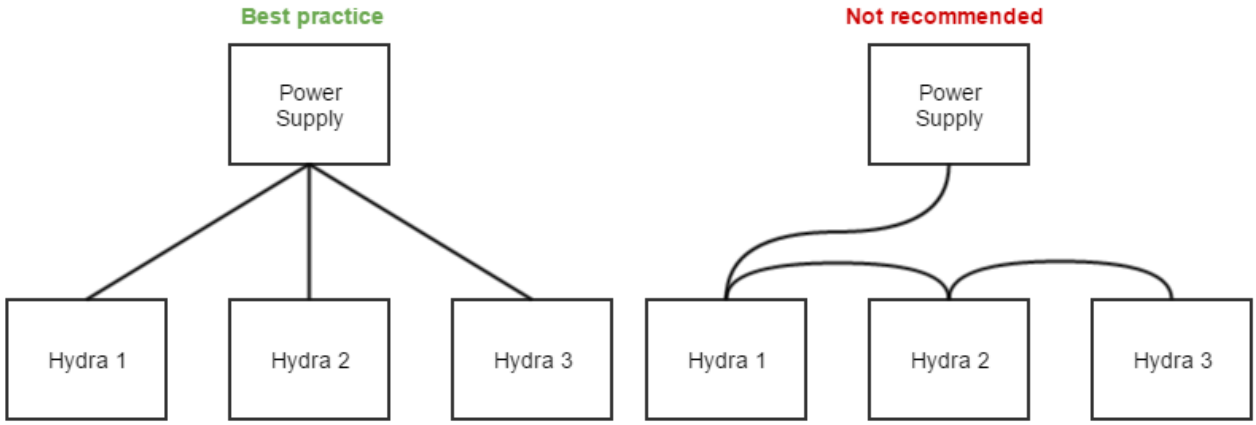
Motor braking current

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 Hydra current ratings.

6.2.4 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.



6.2.5 Power supply wiring recommendations

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 3.5 mm (connector pitch). Following table indicates recommended section for the Hydra Servo Drive:

Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	0.5 mm^2 (20 AWG)	1.5 mm^2 (16 AWG)
Solid wire	0.5 mm^2 (20 AWG)	1.5 mm^2 (16 AWG)

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 0.5 mm^2. Ensure the insulator does not exceed 3.5 mm (connector pitch). Following table indicates recommended wire ferrules for the Hydra Servo Drive:

Manufacturer	Part number	Image	Description
Phoenix Contact	3201369		8 mm pin length, 0.5 mm^2 (20 AWG)
TE Connectivity	966067-1		6 mm pin legth, 0.5 mm^2 (20 AWG)

Wire length

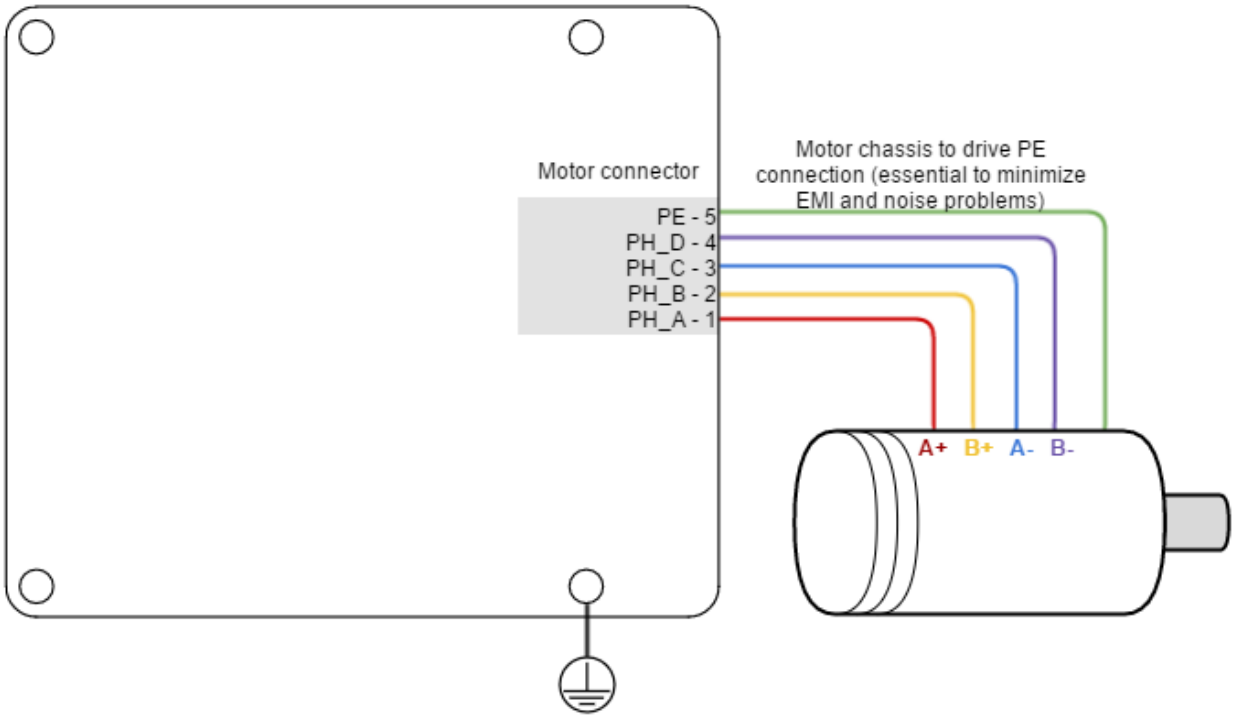
- The distance between the Hydra Servo Drive and the power supply **should be minimized when possible**. Short cables are preferred since they reduce power losses as well as electromagnetic emissions and immunity.
- For best immunity use twisted and shielded 2-wire cables for the DC power supply. This becomes crucial in long cable applications.

- Avoid running supply wires in parallel with other wires for long distances, especially feedback and signal wires.

6.3 Motor and shunt braking resistor

6.3.1 Stepper motors

The Hydra Servo Drive is capable of controlling 4 wire bipolar stepper motors with high performance and precision. The connection diagram is shown in next figure.



Correspondence between Hydra phase names and typical motor phase name conventions is shown in the table below.

Hydra phase name	Alphabetic
PH_A	A+
PH_B	B+
PH_C	A-
PH_D	B-

Common-mode choke

In order to minimize EMI that can affect sensitive signals, the use of a **motor choke** is recommended. **Hydra includes an internal common mode choke**, but further reduction can be achieved with external motor chokes. 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 stepper 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 90º 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.

6.3.2 Motor wiring recommendations

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 3.5 mm (connector pitch). Following table indicates recommended section for the Hydra Servo Drive:

Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	0.5 mm^2 (20 AWG)	1.5 mm^2 (16 AWG)
Solid wire	0.5 mm^2 (20 AWG)	1.5 mm^2 (16 AWG)

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 0.5 mm^2. Ensure the insulator does not exceed 3.5 mm (connector pitch). Following table indicates recommended wire ferrules for the Hydra Servo Drive:

Manufacturer	Part number	Image	Description
WAGO	216-201		0.5 mm^2 (20 AWG)
WAGO	216-224		1.5 mm^2 (16 AWG)

Motor choke

Hydra Servo Drive has an onboard common-mode choke to minimize its electromagnetic emissions (Z = 240 Ω @ 4 MHz). However, in applications where electromagnetic compatibility is a concern or that must comply with the EMC standards, an external common mode choke can be added. 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 a choke that fits the Hydra Servo Drive specifications.

Type	Manufacturer	Reference
Low frequency ferrite	Laird Technologies	LFB360230-300

Wire length

- The distance between the Hydra 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 Hydra 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.

6.3.3 Shunt braking resistor

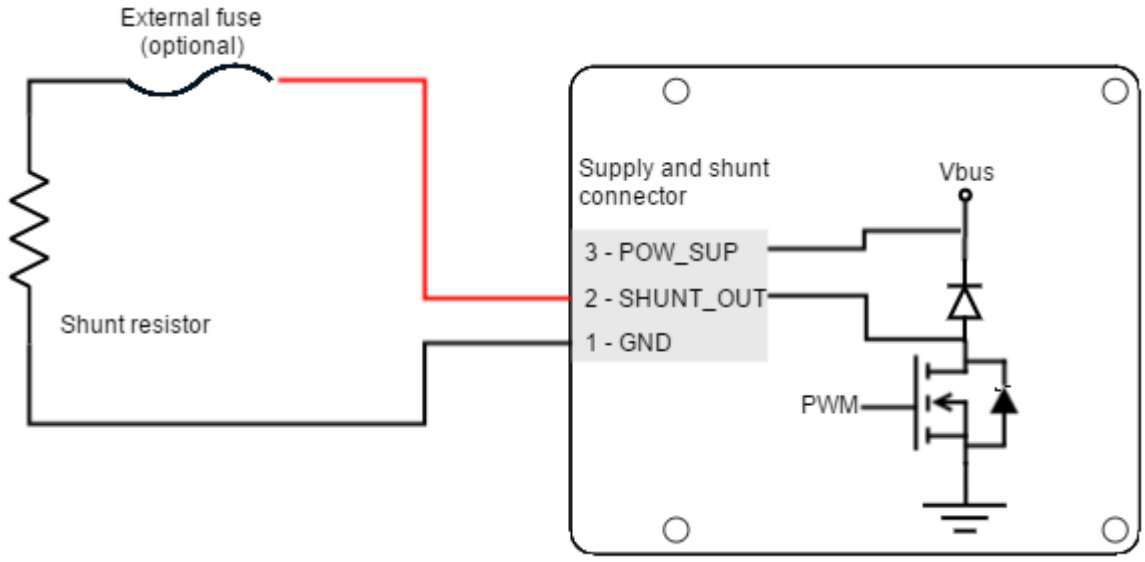
While decelerating a motor (abrupt motion brakes or reversals), the mechanical energy is converted into electrical energy by the motor. This energy is regenerated into the power supply and could lead to an increase of the supply voltage. To absorb this energy the **Hydra incorporates a shunt transistor to connect an external braking resistor.**

Wiring recommendations of the shunt braking resistor:

- The external braking resistor should be connected between SHUNT_OUT and POW_SUP terminals of the Hydra Supply and shunt connector.
- It is strongly recommended to use an external fuse to limit the maximum power dissipation according to the chosen shunt resistor.
- **Wire section should be, at least, like the motor wires**.
- Shunt resistor connections should be as short as possible to reduce parasitic inductances.

Shunt resistor calculation tool

Additional information on shunt braking resistor sizing and a calculation tool can be found here.



Hot surfaces

Be careful, shunt resistor may have hot surfaces during operation.

Configuration of the shunt

The shunt transistor can be configured using parameters in the register 0x2103 - Shunt configuration. When the supply voltage reaches the maximum voltage indicated in register 0x2101 - Drive bus voltage, the shunt transistor is activated.

As a recommendation, set the DC bus voltage limit above the maximum expected DC supply voltage + 5%.

When using batteries set the DC bus voltage limit below the maximum charge voltage. This will allow regenerative braking and protect the battery against overcharging.

6.4 Feedback connections

The Hydra Servo Drive has a feedback connector for connecting differential or single-ended digital incremental encoders.

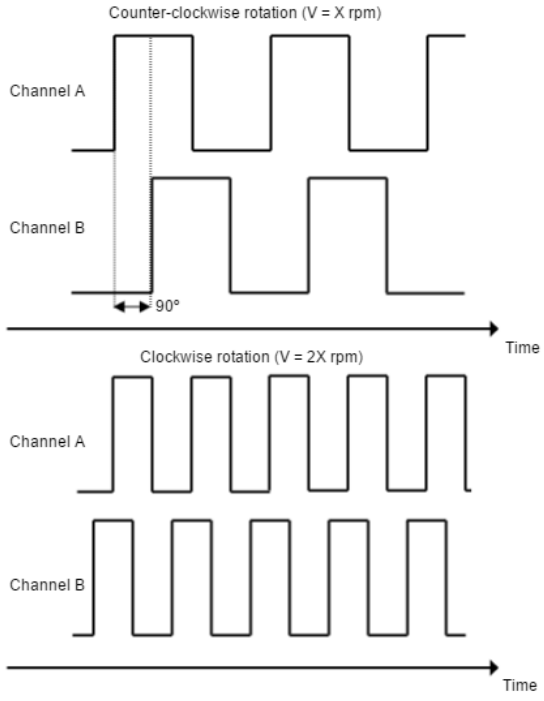
Hydra also provides a 5V, 200 mA outputs for feedbacks supply. This output is overload and short circuit protected.

6.4.1 Digital Incremental Encoder

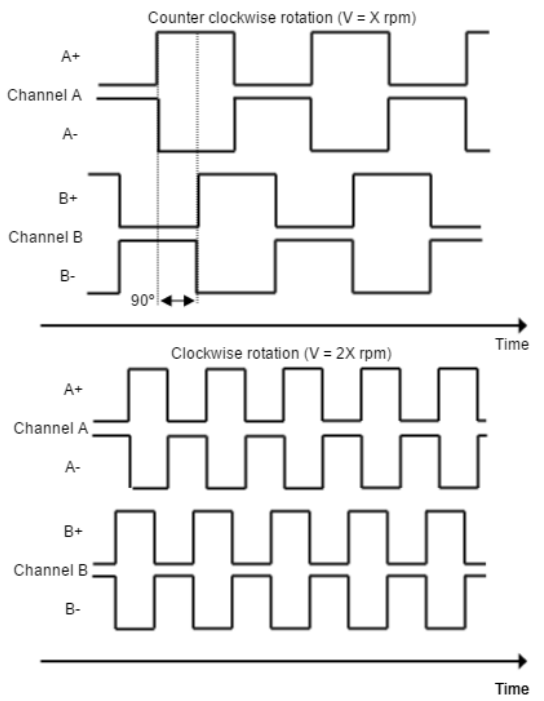
Hydra can use single ended or differential digital incremental encoder inputs (also known as quadrature incremental encoders) for velocity and/or position control, as well as commutation sensor. The encoder provides incremental position feedback that can be extrapolated into precise velocity or position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

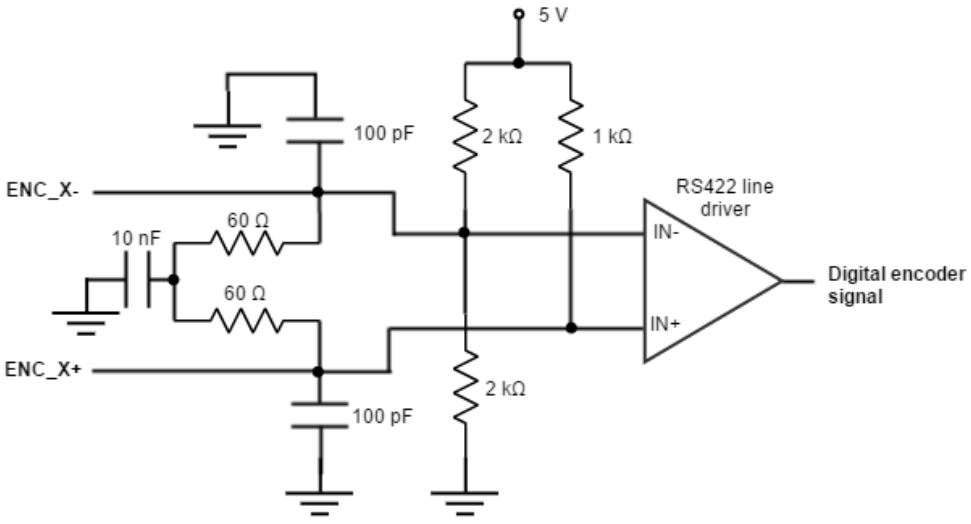
The Hydra Servo Drive has one differential digital encoder interface, with optional index signal input. Index signal (Z) is a single pulse per revolution signal that can be used to know absolute positions. Next table illustrates digital encoder inputs main features.

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)
Nominal voltage range	0 ~ 5 V
Maximum voltage range	-0.5 ~ 5.5 V
Maximum recommended working frequency	10 MHz (differential)
1st order filter cutting frequency (-3 dB)	6.6 MHz
Maximum readable pulse frequency	30 MHz
Termination resistor	120 Ω (between ENC_x+ and ENC_x-)
Bias resistors	ENC_x+ (positive input) 1 kΩ to 5 V ENC_x- (negative input) 1 kΩ to 2.5 V (equivalent)

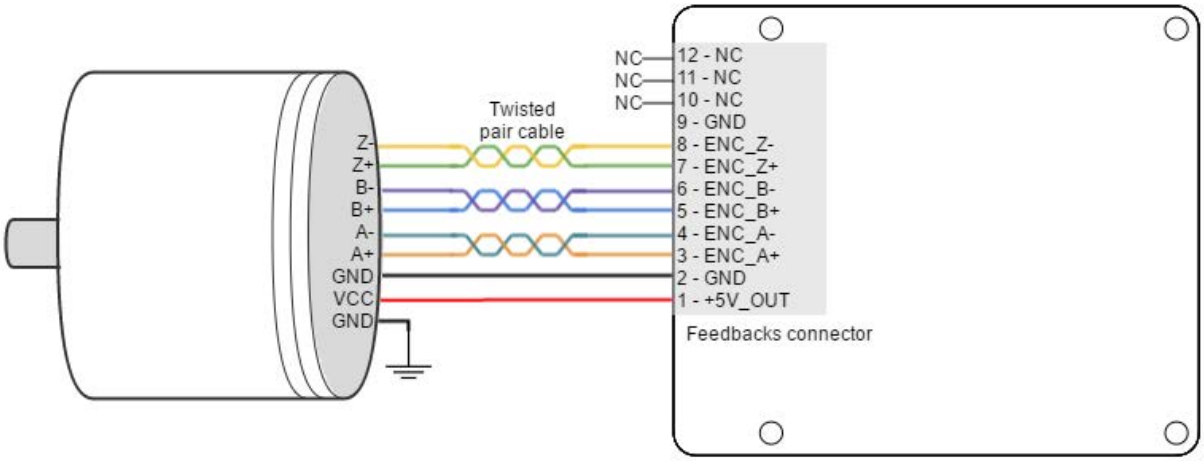
For encoder signal reception, an RS-422 differential line receiver is used. The high signals (ENC_A+, ENC_B+ and ENC_Z+) are pulled up to +5 V, and the low signals (ENC_A-, ENC_B- and ENC_Z-) are biased to 2.5 V. This arrangement let the user to connect either differential output encoders or single ended encoders (both open collector and totem pole).

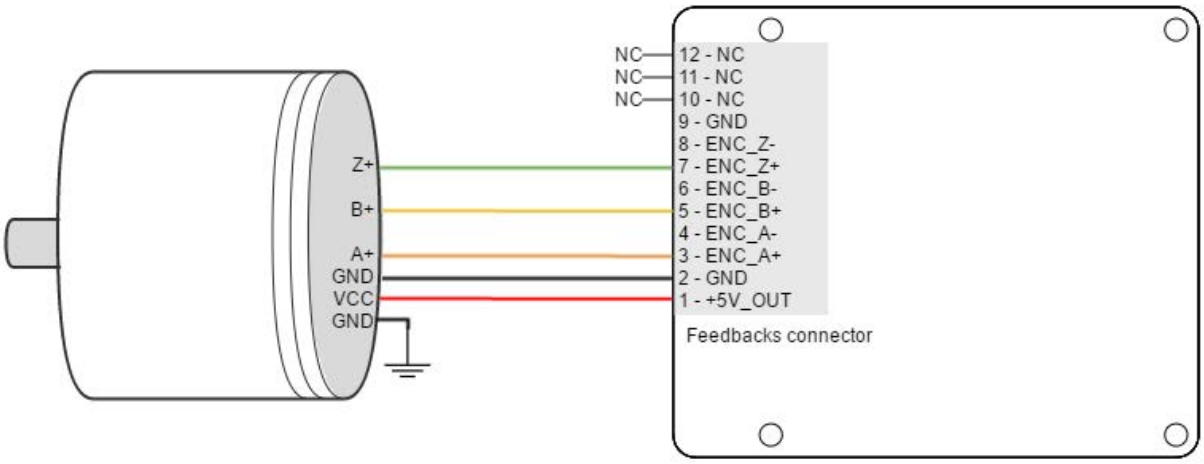
The encoder interface also accepts an RS-422 differential quadrature line driver signal in the range of 0 V to 5 V, up to 10 MHz. When single ended encoder is connected, only high signals (ENC_A+, ENC_B+ and ENC_Z+) must be used.

The Hydra digital encoder input includes a 120 Ω termination resistor with split topology. This topology consists in two 60 Ω resistors in series with the middle point decoupled to GND with a 10 nF capacitor. 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 Hydra Servo Drive. Refer to Feedback wiring recommendations for more information about connections and wires.





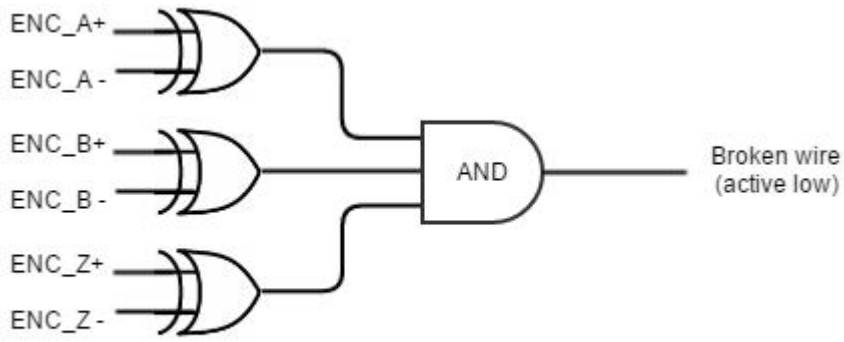
Digital encoders with single ended 24 V outputs

Hydra Servo Drive can also interface single ended digital encoders with output voltages higher than 5 V, for instance 24 V PLC level encoder. With the use of series connected limiting resistors, Hydra is able to read encoder counts correctly while the inputs are correctly protected.

It is recommended to use a 4.7 kΩ 1/4 W resistor in series with the ENC_X- (inverting) input and leave the ENC_X+ floating.

Encoder broken wire detection

Hydra Servo Drive includes a broken wire detection circuit. The circuit is based on 3 EX-OR gates that will generate an error if the encoder is disconnected or a wire is broken. **This system only works for differential encoders.**



Note: Inputs must be differential. Positive and negative signals for any encoder line must be different to avoid broken wire detection.

> **Encoder without Index (Z) line**
>
> To avoid a broken wire fault when the differential encoder has no index (Z) line, connect the negative pin (ENC_Z-) to GND (this ensures the XOR result = 1) or configure the encoder as single ended in MotionLab.

6.4.2 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 Hydra and encoder GND signals** even if the encoder supply is not provided by the drive.
- **Connection between Hydra 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.

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 and shunt braking resistor 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.

6.5 I/O connections

The Hydra 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.

Alternative assembly options

Under a custom purchase order, Hydra Servo Drive can be provided with a Torque Off input.

Wiring recommendations

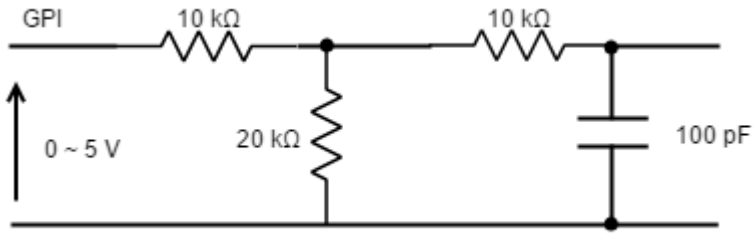
Wiring recommendations for I/O signals are the same than for feedback signals. Detailed information about good wiring practices can be found in Feedback wiring recommendations.

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

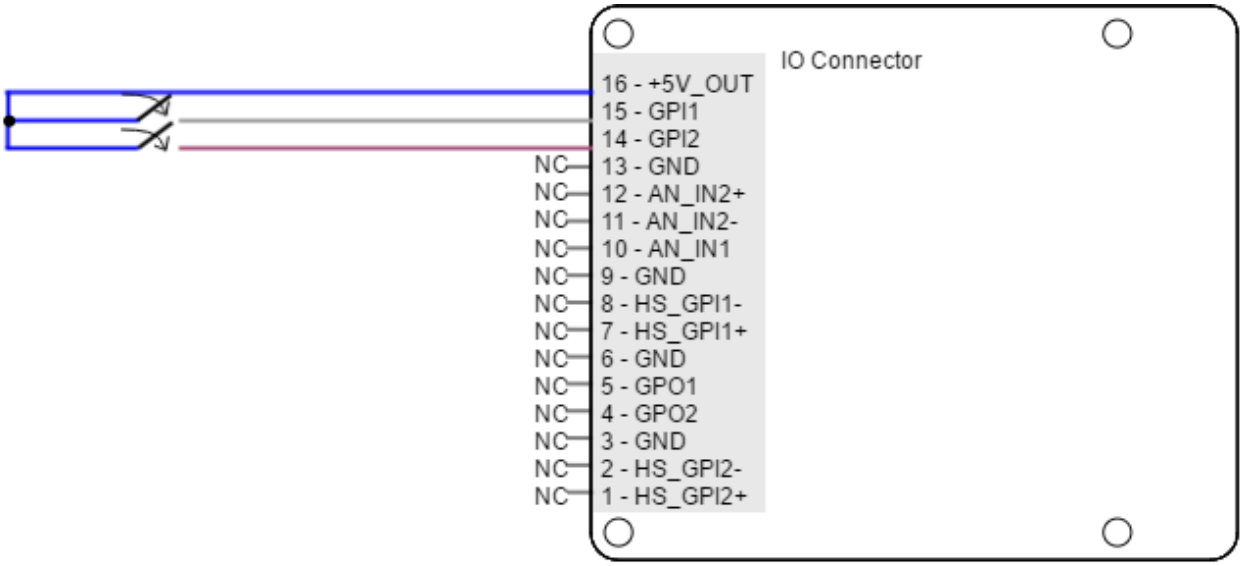
The general purpose non-isolated digital inputs are ready for 5 V levels, but are 24 V tolerant. Next table show their electrical specifications.

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
High level input voltage	4.5 V < Vin < 24 V
Low level input voltage	0 < Vin < 1 V
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:



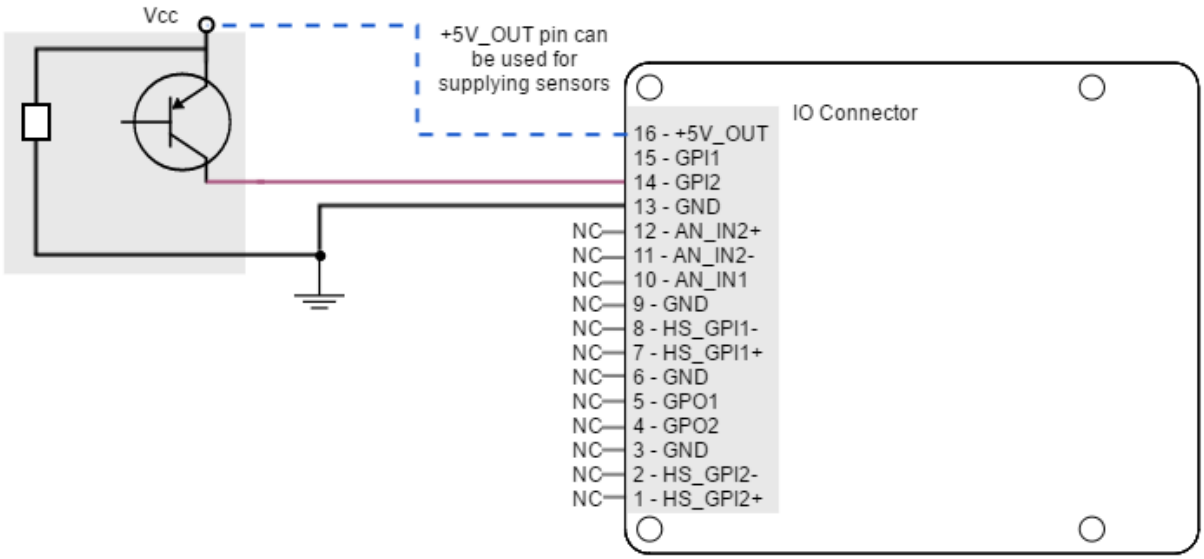
Next figure shows an example of how to connect a switch to the GPI, using +5V_OUT (pin 16) pin as a supply source.

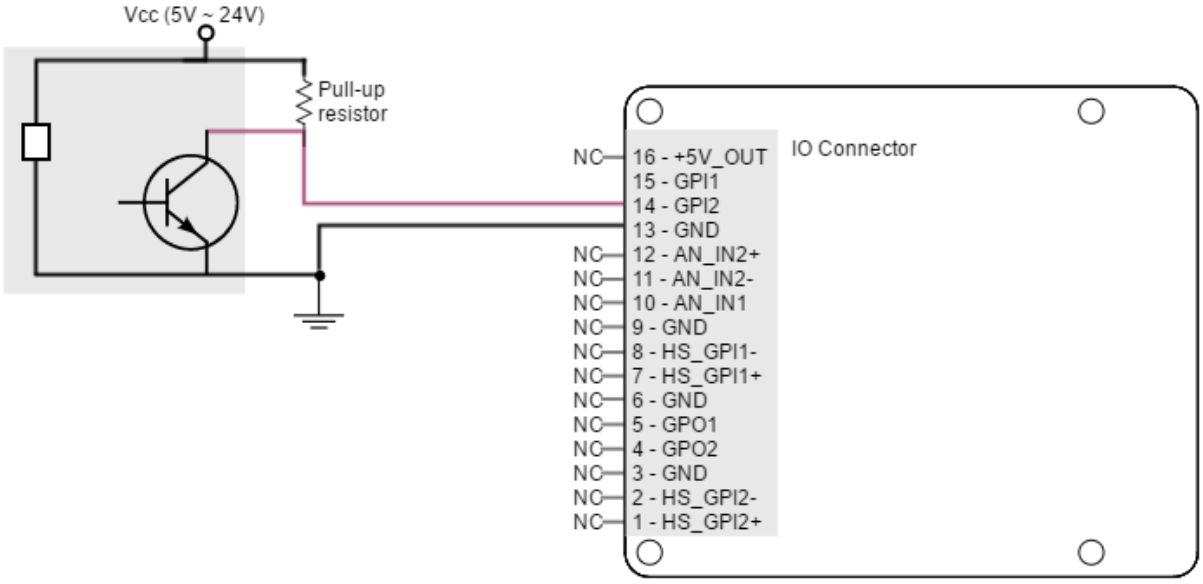


Non-isolated I/O

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

Hydra 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.

6.5.2 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

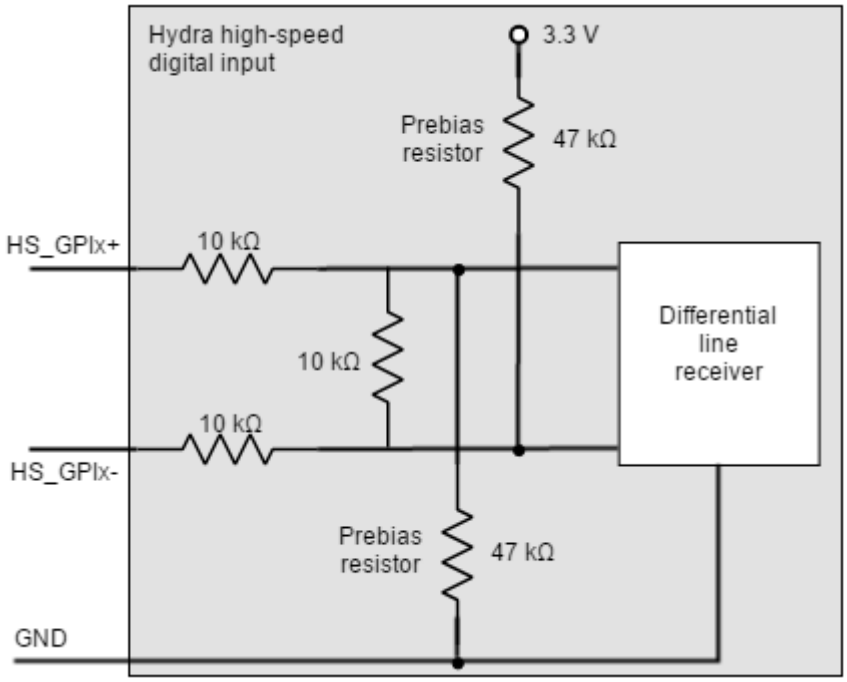
Hydra high-speed inputs are default low-level (OFF). When no signal or load is connected, the board will detect a logic low.

Specification	Value for 5 V inputs
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 ≤ V_{CM} ≤ 12 V

Next figure shows the circuit model for high-speed digital input. Input is composed of a 3-resistor differential divider, with 10 kΩ resistors, resulting in a total input impedance of 30 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:



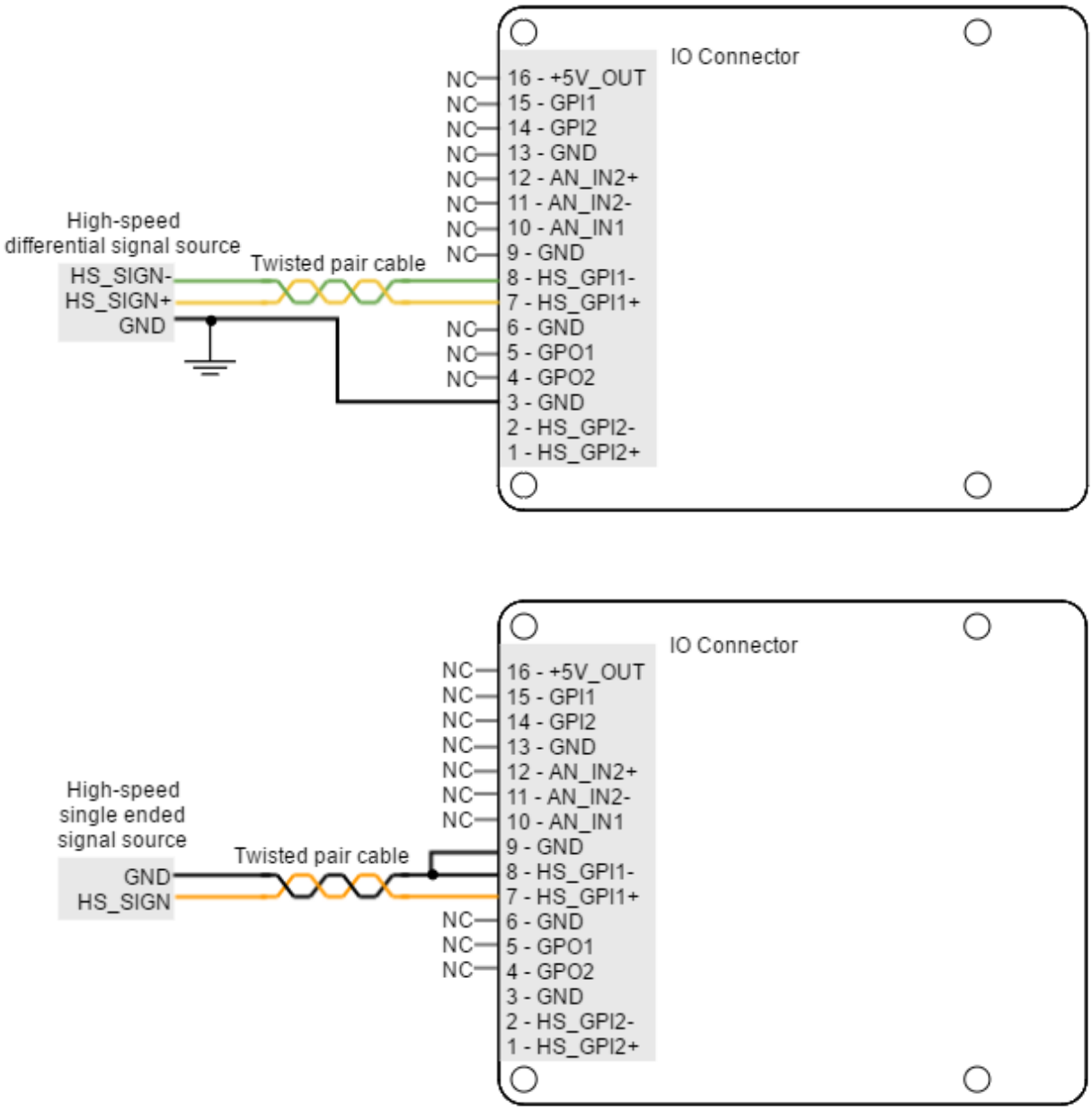
Single ended operation of HS_GPI

In order to use the high-speed digital input in single ended mode, connect HS_GPIx- to GND and HS_GPI+ to the desired input signal.

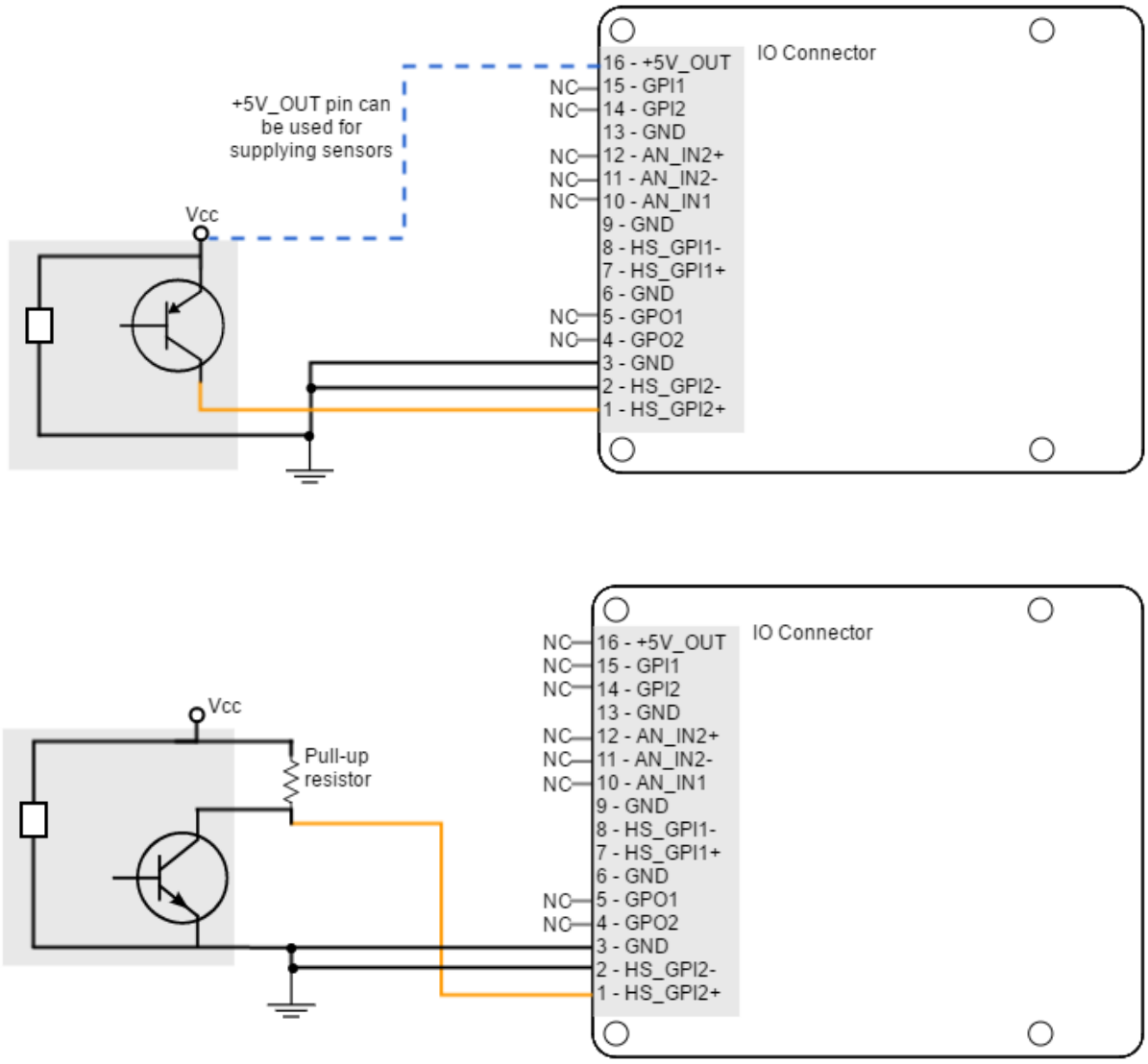
Non-isolated I/O

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

Next figures illustrate how to connect high-speed differential and single ended signals to HS_GPI1 (same wiring can be used for HS_GPI2).



Hydra 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.

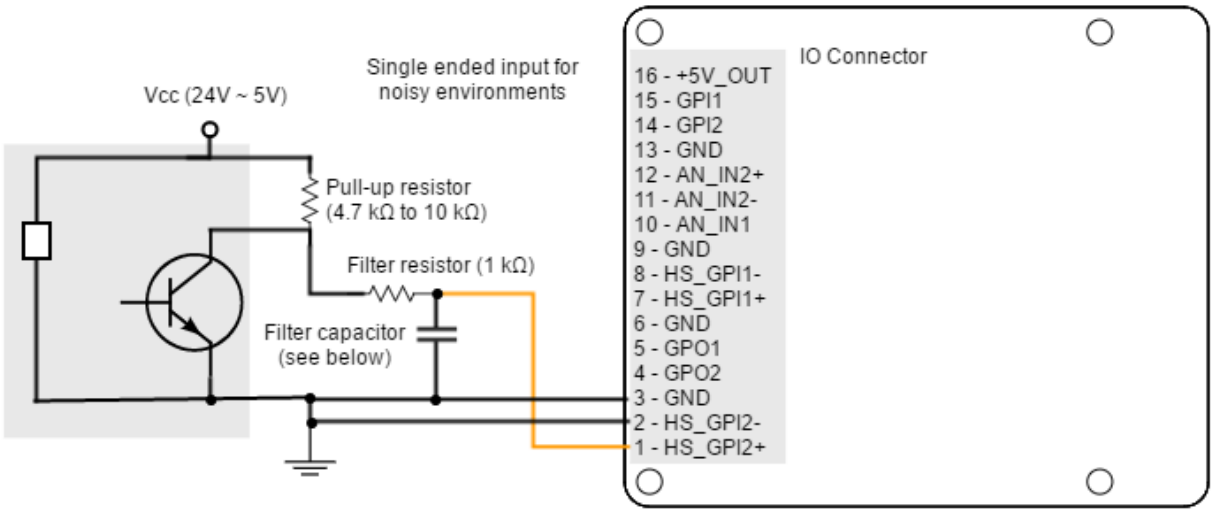


HS_GPI pull-up resistors

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 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, 47 kΩ 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

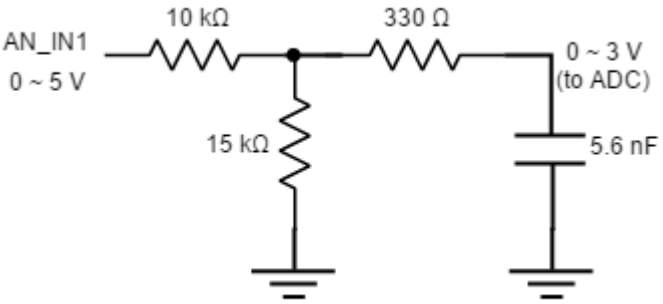
Cfilter ≤ 1000 / (12 * Freq * (Rfilter + Rpull-up))
Cfilter is in nF. Freq is the maximum signal frequency in kHz. Rfilter and Rpull-up are in kΩ.
Choose the biggest standard capacitance close to Cfilter.
Use ceramic or film (MKP, MKT) capacitors, place them as close as possible to the driver.

6.5.3 Analog inputs interface (AN_IN1, AN_IN2)

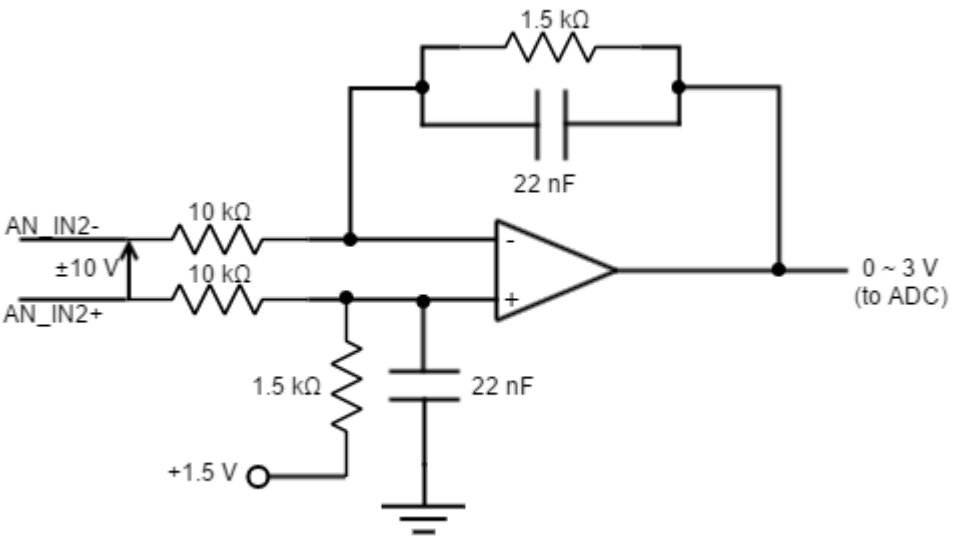
Hydra Servo Drive has two 12-bit analog inputs, a single ended one (AN_IN1) and a differential one (AN_IN2). Each one of them has a different input voltage range. Next table summarizes the main features of the analog inputs:

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)	24 V	
1st order filter cutting frequency (-3dB)	4.5 kHz	4.8 kHz
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:



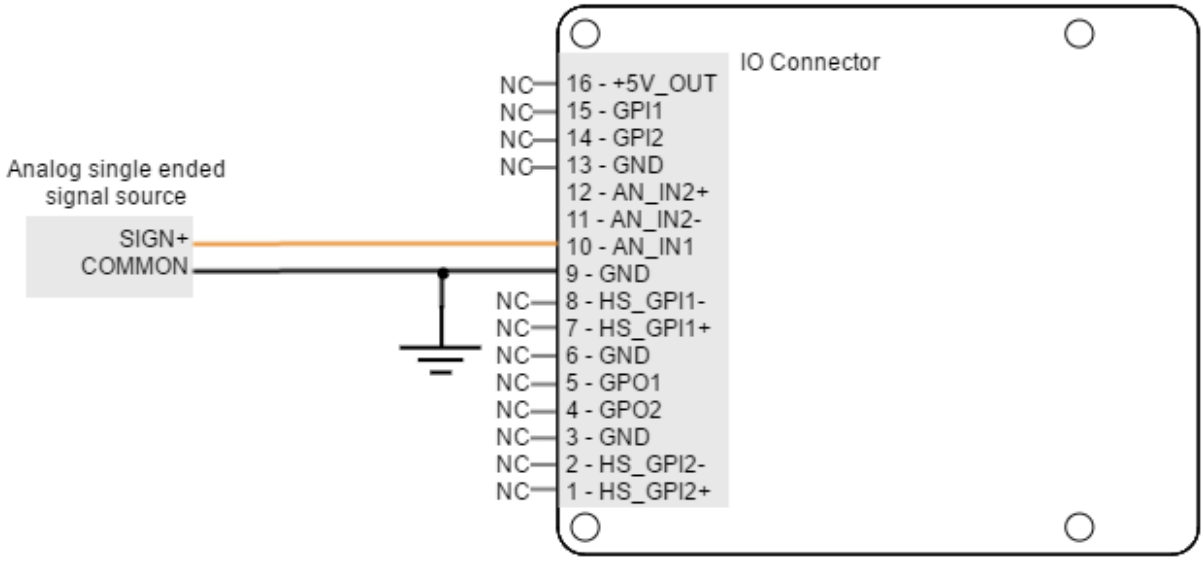
Extending AN_IN1 voltage range

To get a 0 ~ 10 V input range in AN_IN1 input, place a 25 kΩ resistor in series with the input.

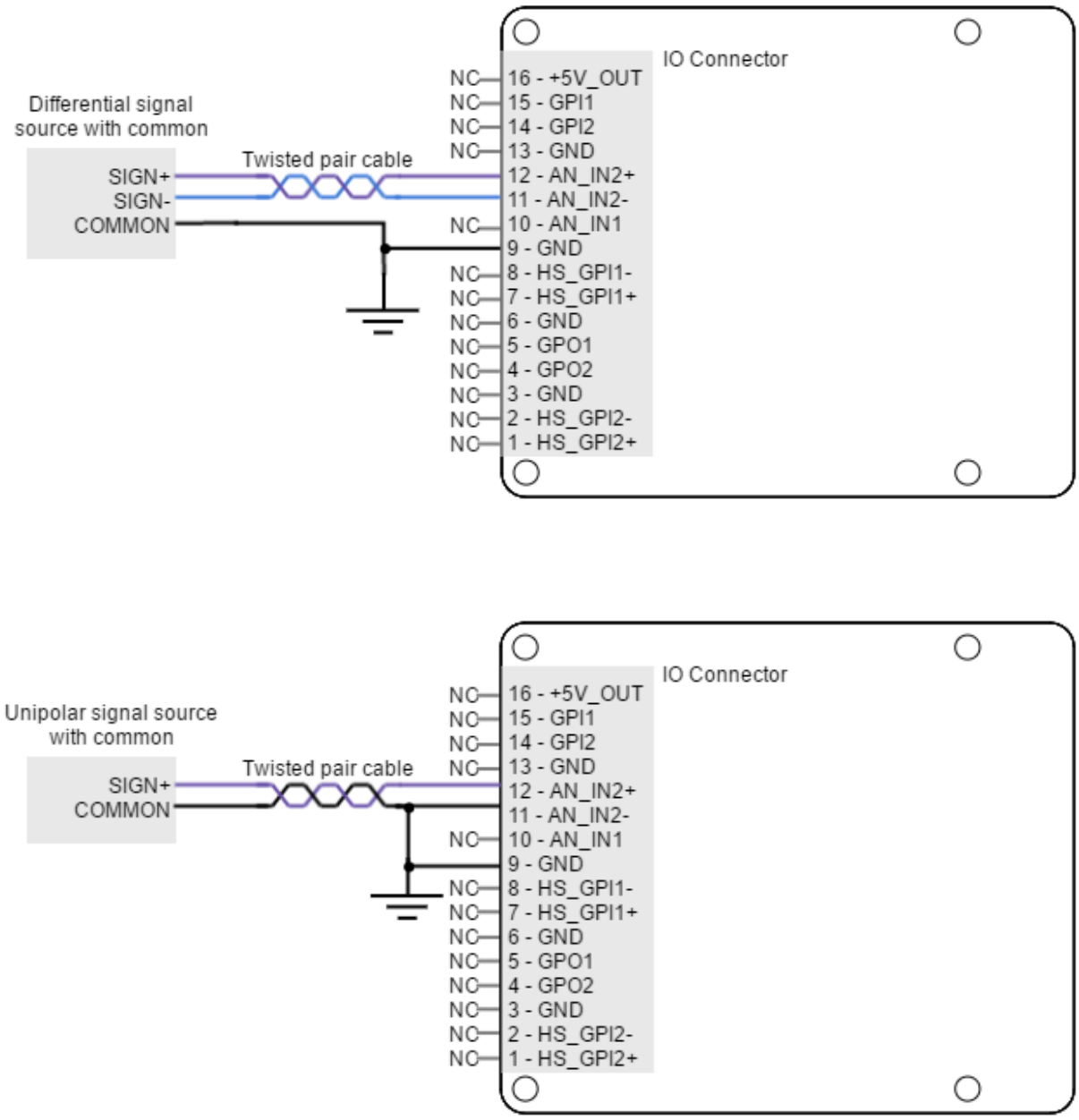
Non-isolated I/O

Hydra Inputs and outputs are not isolated. The ground of the Hydra 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 Hydra 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.



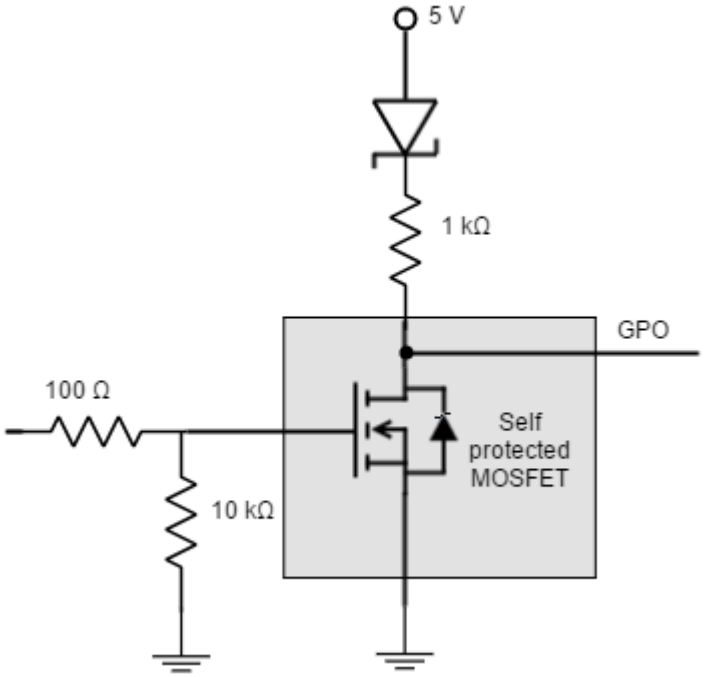
6.5.4 Digital outputs interface (GPO1, GPO2)

Hydra 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 R_{load} = 100 kΩ 20 µs @ 5 V and R_{load} = 100 kΩ
OFF_ON delay	15µs @ 30 V and R_{load} = 100 kΩ 50 µs @ 5 V and R_{load} = 100 kΩ
Max working frequency	1 kHz

Next figure shows digital outputs circuit model.

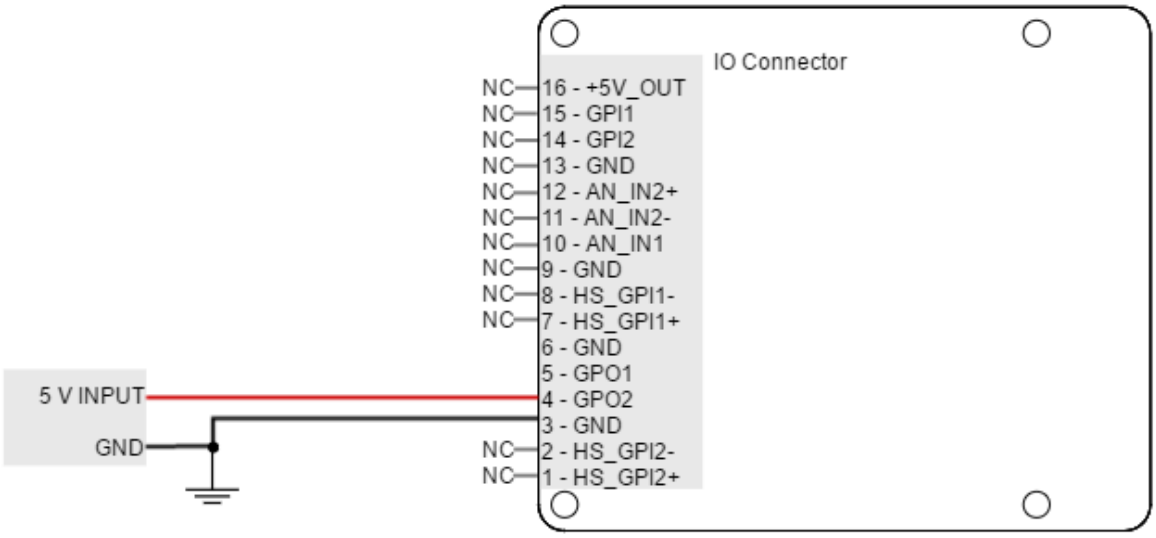


Non-isolated I/O

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

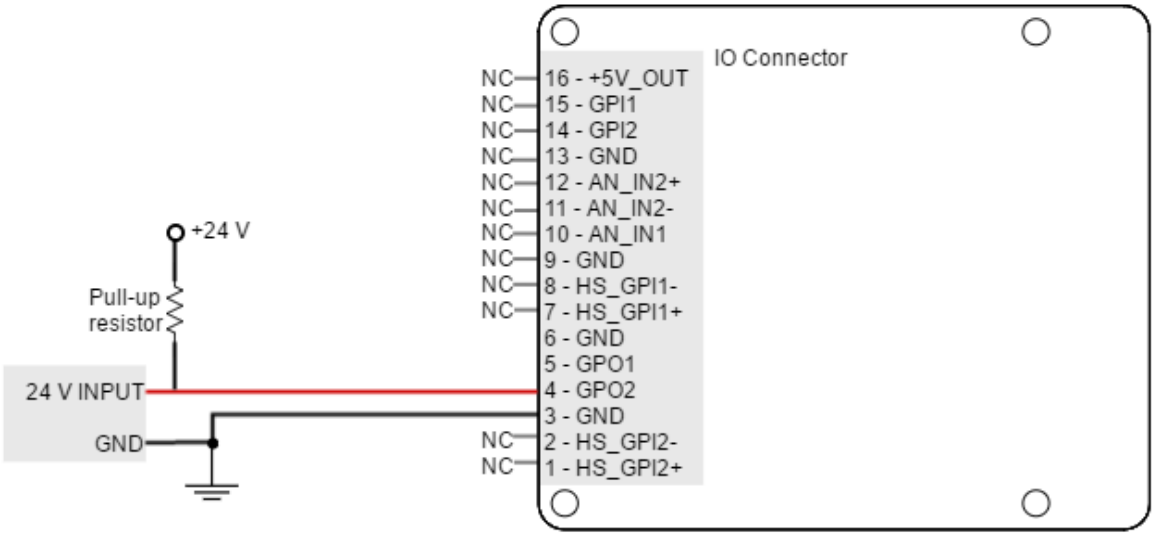
Wiring of 5V outputs

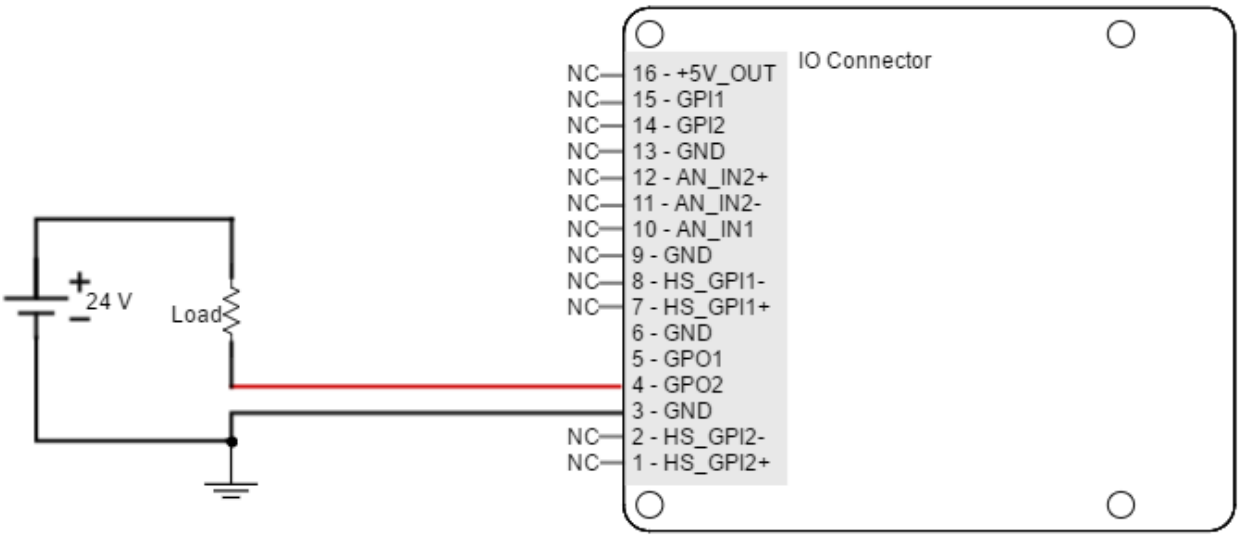
Loads that require 5V as high-level voltage can be connected directly to the digital output. A wiring example for GPO2 is shown in the next figure (same wiring could be used for GPO1).



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).





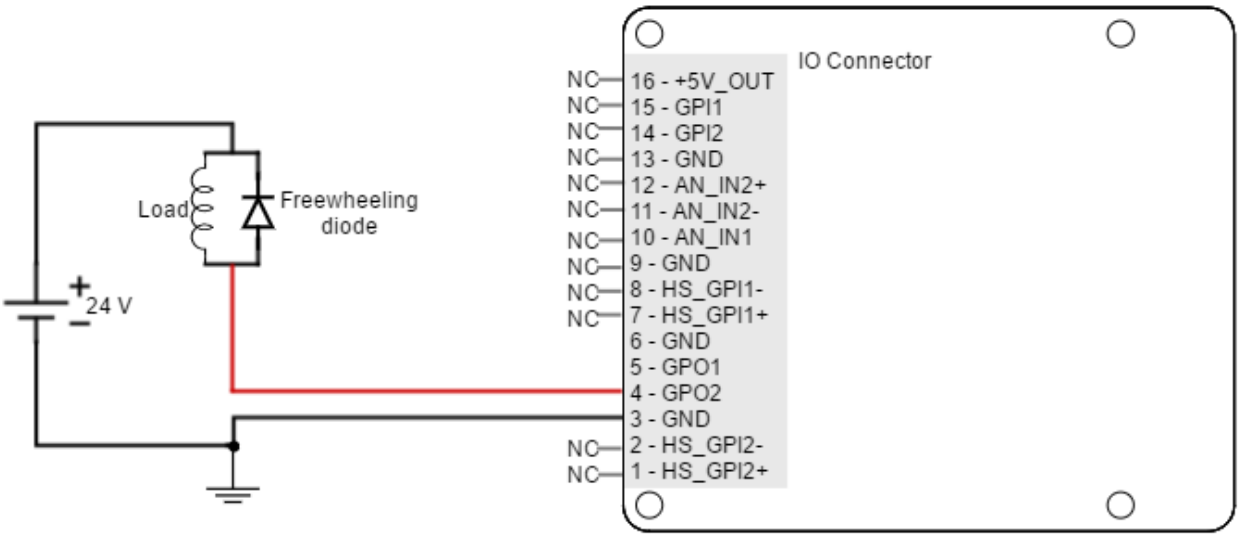
Interfacing inductive loads

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).



6.5.5 Motor brake output (GPO1, GPO2)

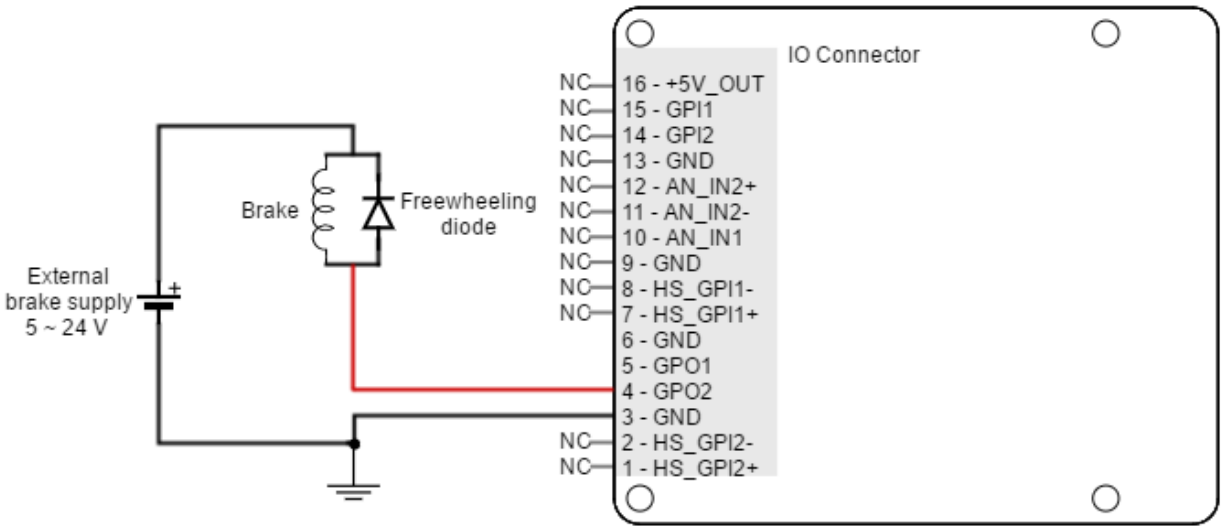
Electromechanical brakes are needed in critical applications where the disconnection of the motor or a lack of electric braking could be dangerous or harmful (i.e. falling suspended loads). Hydra Servo Drive can use the digital outputs (GPO1 and GPO2) as a brake output. This output consists on an open 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.

6.5.6 Torque off input (custom purchase order)

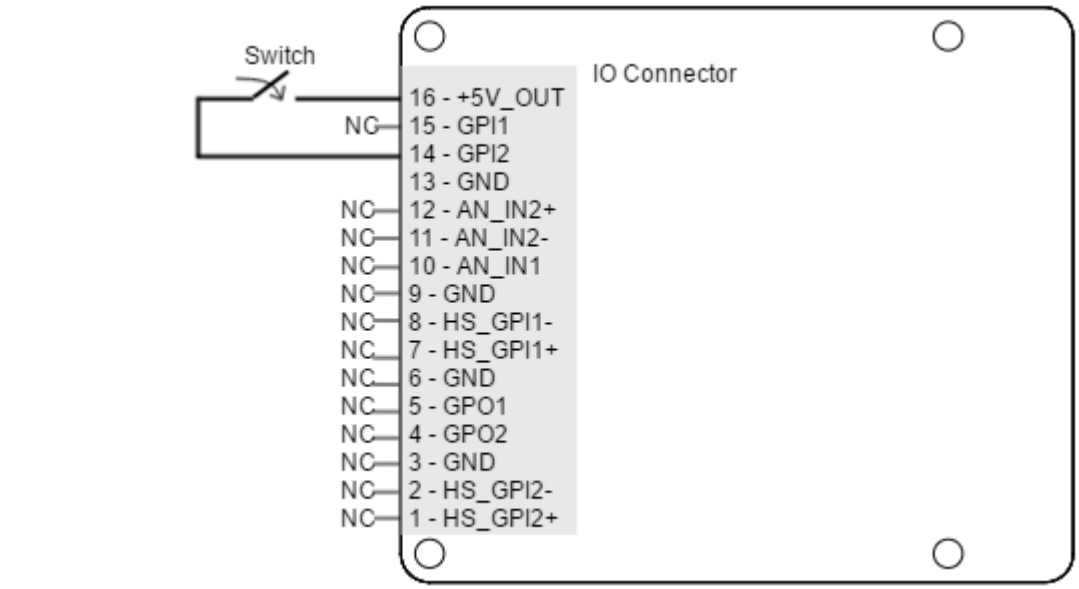
As assembly option (custom purchase order), the Hydra Servo Drive can be provided with a torque off input. This input is used to prevent motor torque in an emergency event while Hydra remains connected to the power supply.

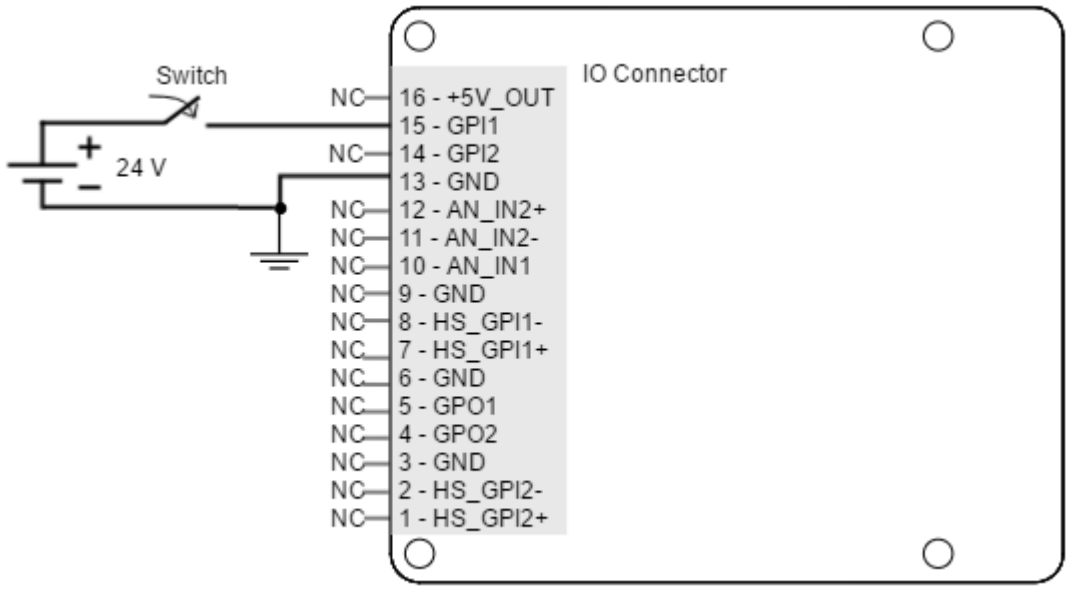
The torque off input can be implemented through input **GPI2**. When a **LOW level** voltage is detected in this input, **the transistors of the power stage are turned off** and a STO fault is notified. During this state, no torque will be applied to the motor no matter configuration, or state of a command source. This will slow down the motor shaft until it stops under its own inertia and frictional forces. This input should not be confused with a digital input configured as enable input, because enable input is firmware controlled and does not guarantee intrinsic safety as it can be reconfigured by a user.

Not a Safe Torque Off

The torque off input is not a safety critical torque off input (Safe Torque Off). It should not be used for safety critical applications.

GPI2 input reads a logic low state (0 V < V_{in} < 1 V) by defect, so the input must be connected to a logic high level (4 V < V_{in} < 24 V) to activate the power stage. Next figures show two examples of connection of the torque off input, a self-supplied option and an external supplied option.





6.6 Command sources

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

- Network communication interface (USB, CANOpen or RS-485)
- 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.

6.6.1 Network communication interface

Hydra Servo Drive can utilize network communication as a form of input command. Supported network interfaces for Hydra Servo drive are CAN (CANopen protocol), USB and RS-485.

USB interface is not suitable for long distances or noisy environments. This protocol is only recommended for configuration purposes.

For normal operation, it is suggested to use CAN or RS-485. These interfaces are more robust against noise than USB, and allow higher distances between the Hydra Servo Drive and the commander. These command sources can be used for setting position, velocity or torque target.

For further information, see Communications section.

6.6.2 Standalone

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

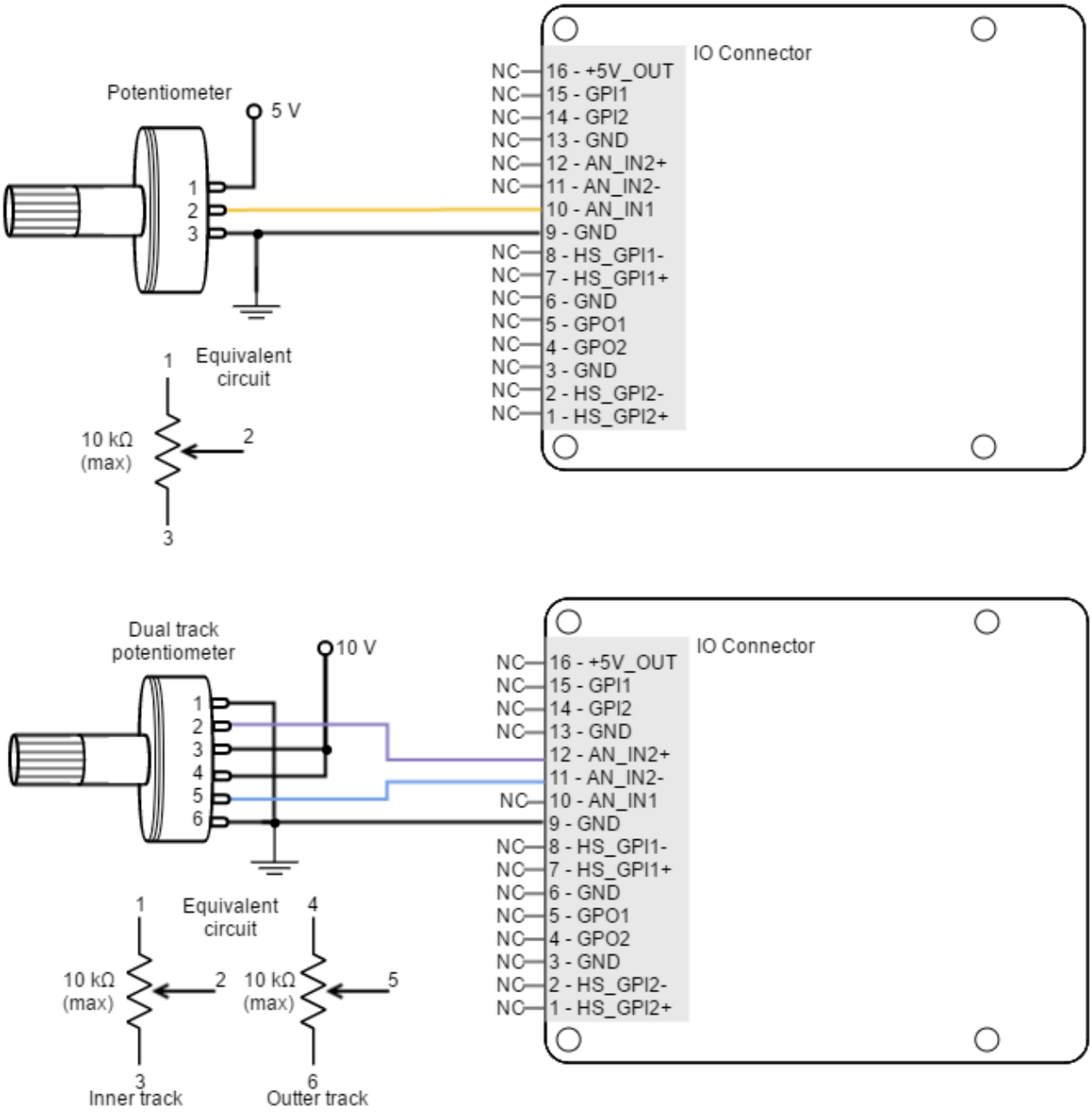
Programs or macros composed with Motion Lab suite allow to **configure position, velocity or torque targets** and to **interface with general purpose inputs and outputs.**

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.

6.6.3 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. Hydra 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.

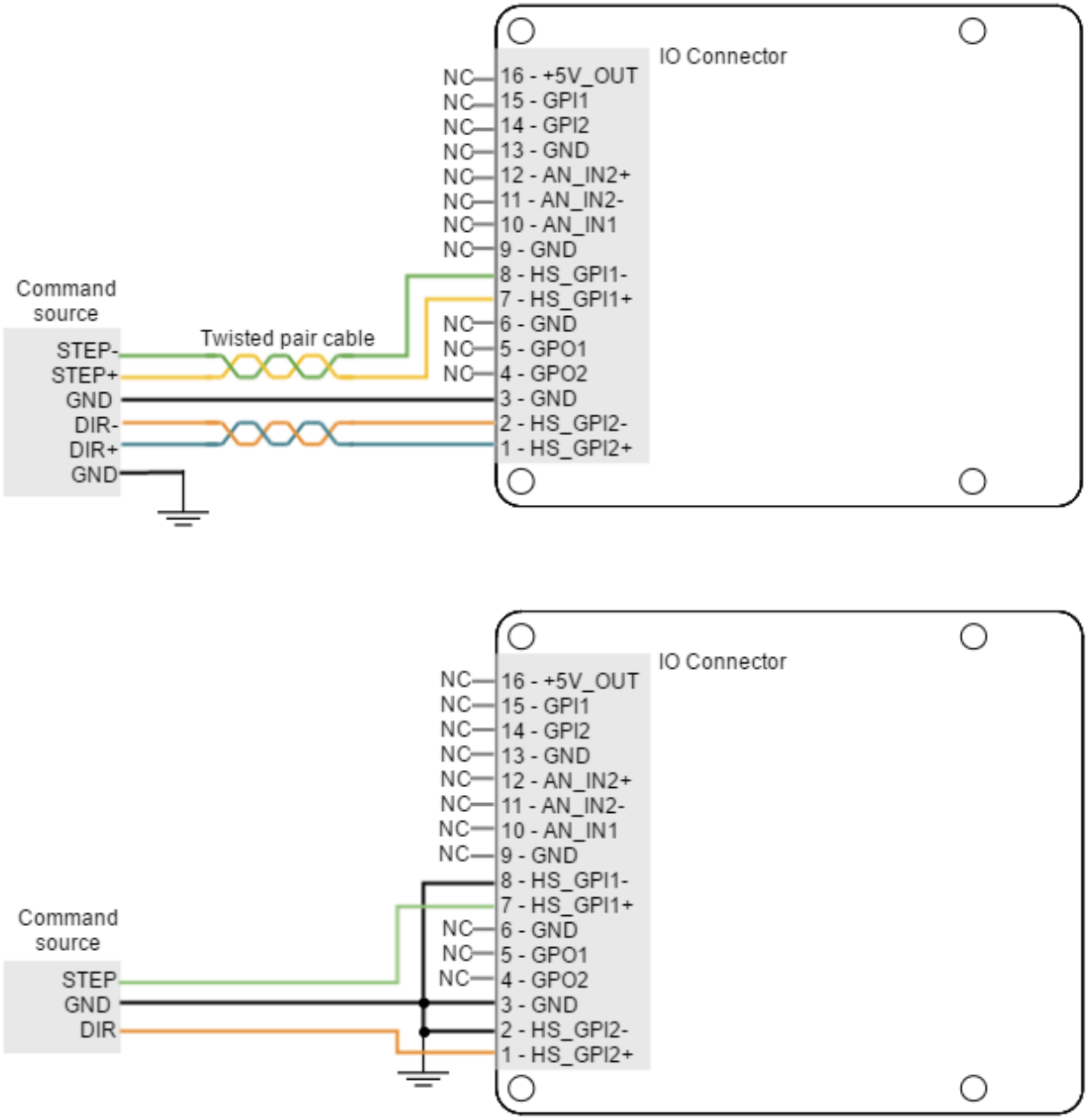
A common application of the analog command source is the use of joysticks (or other kinds of potentiometers) for controlling the position or velocity of a system. As application examples, the following figures show how to connect a potentiometer to the single ended analog input (AN_IN1) and a dual track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



6.6.4 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 Hydra Servo Drive.



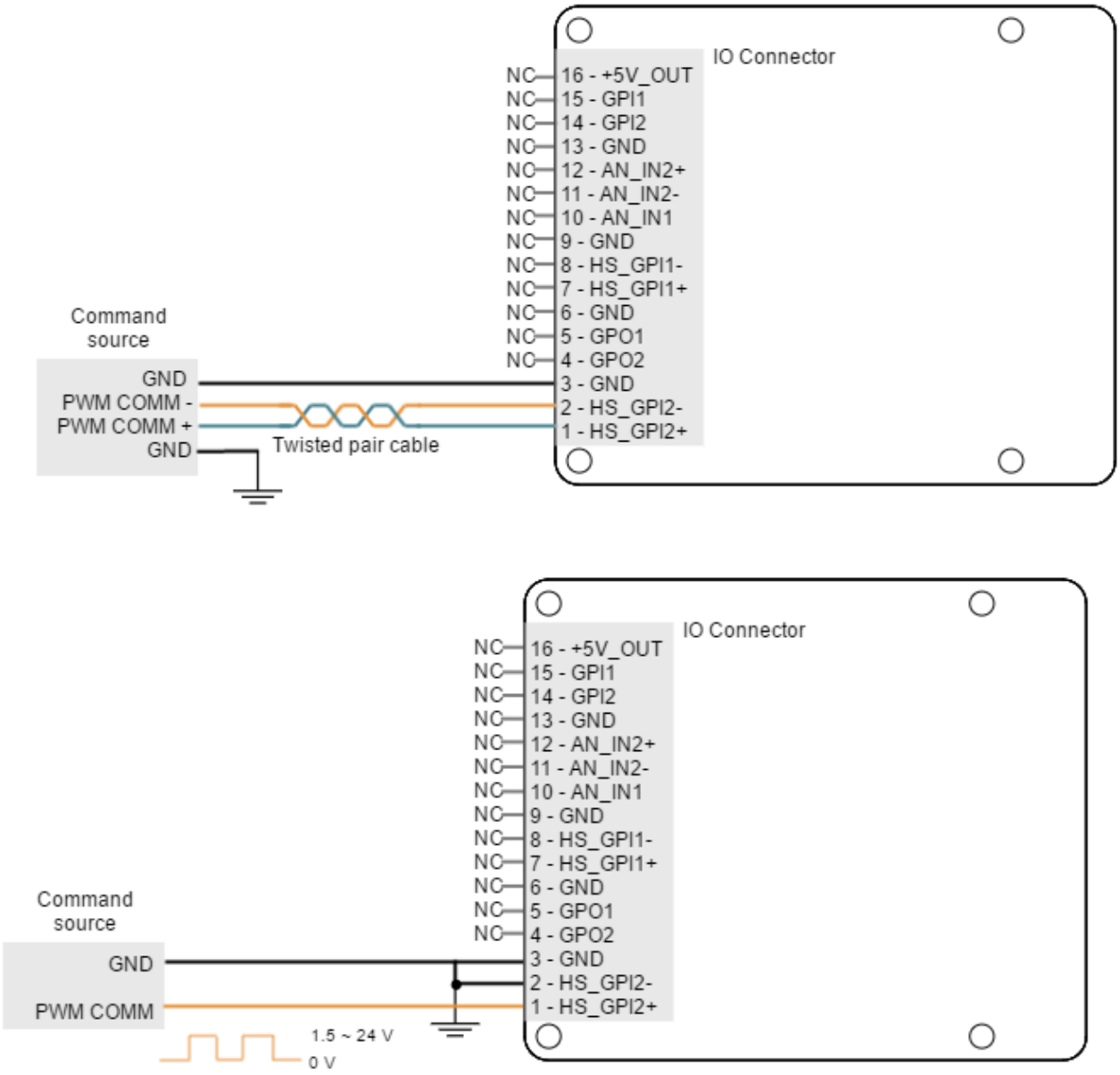
6.6.5 PWM command

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.

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.



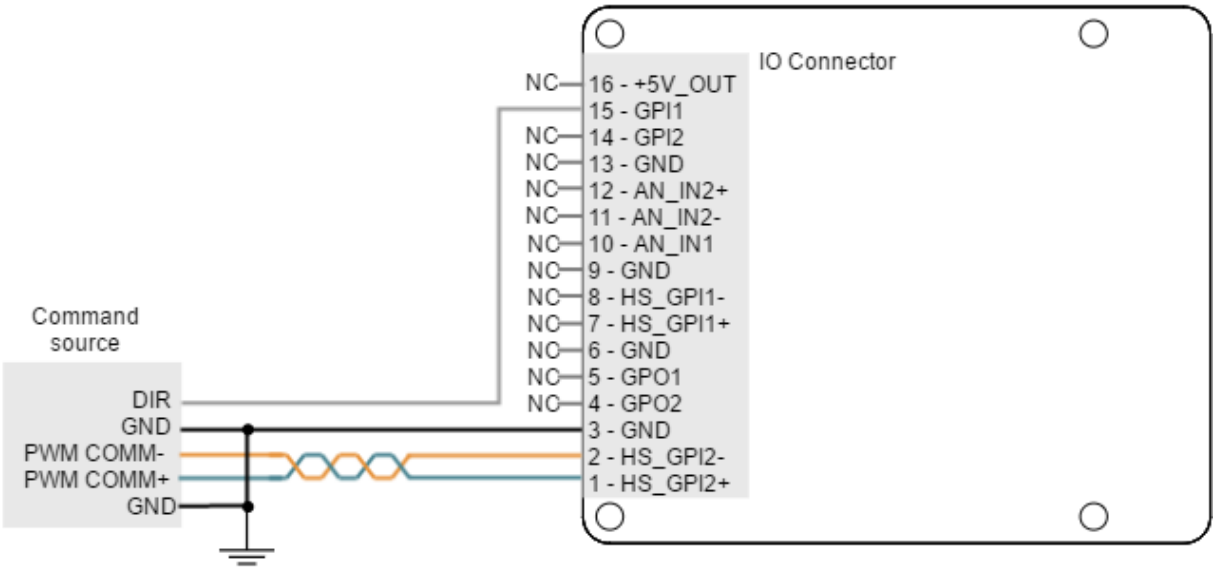
Dual input mode

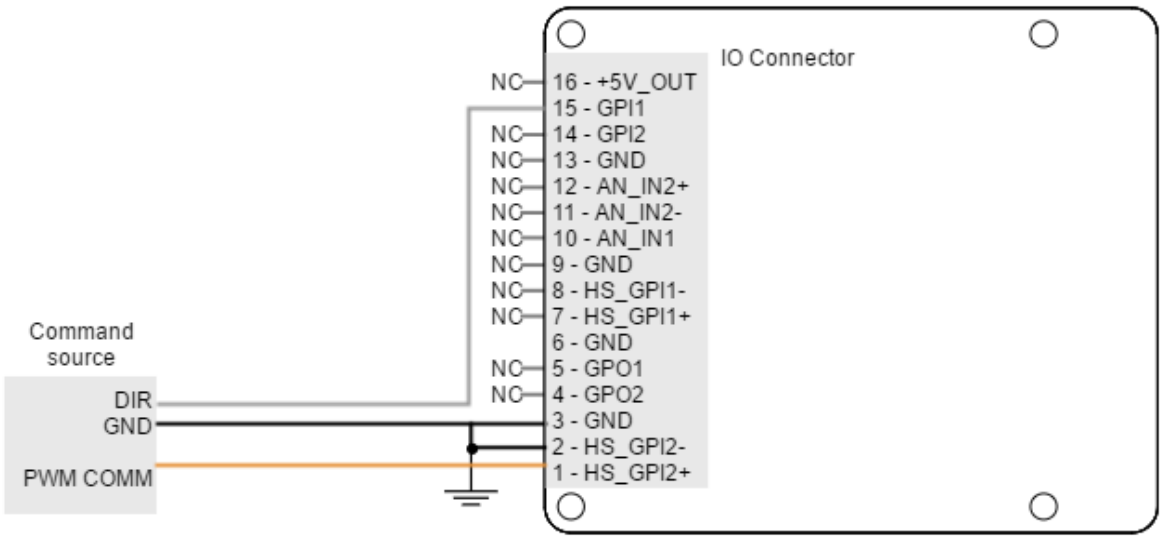
Dual input mode uses two signal lines, a PWM signal whose duty cycle sets the target position, velocity or torque, and a Direction signal that indicates the rotation direction (i.e., logic low or "0" for clockwise rotation and logic high or "1" for counter-clockwise rotation). In this mode, a duty cycle 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.

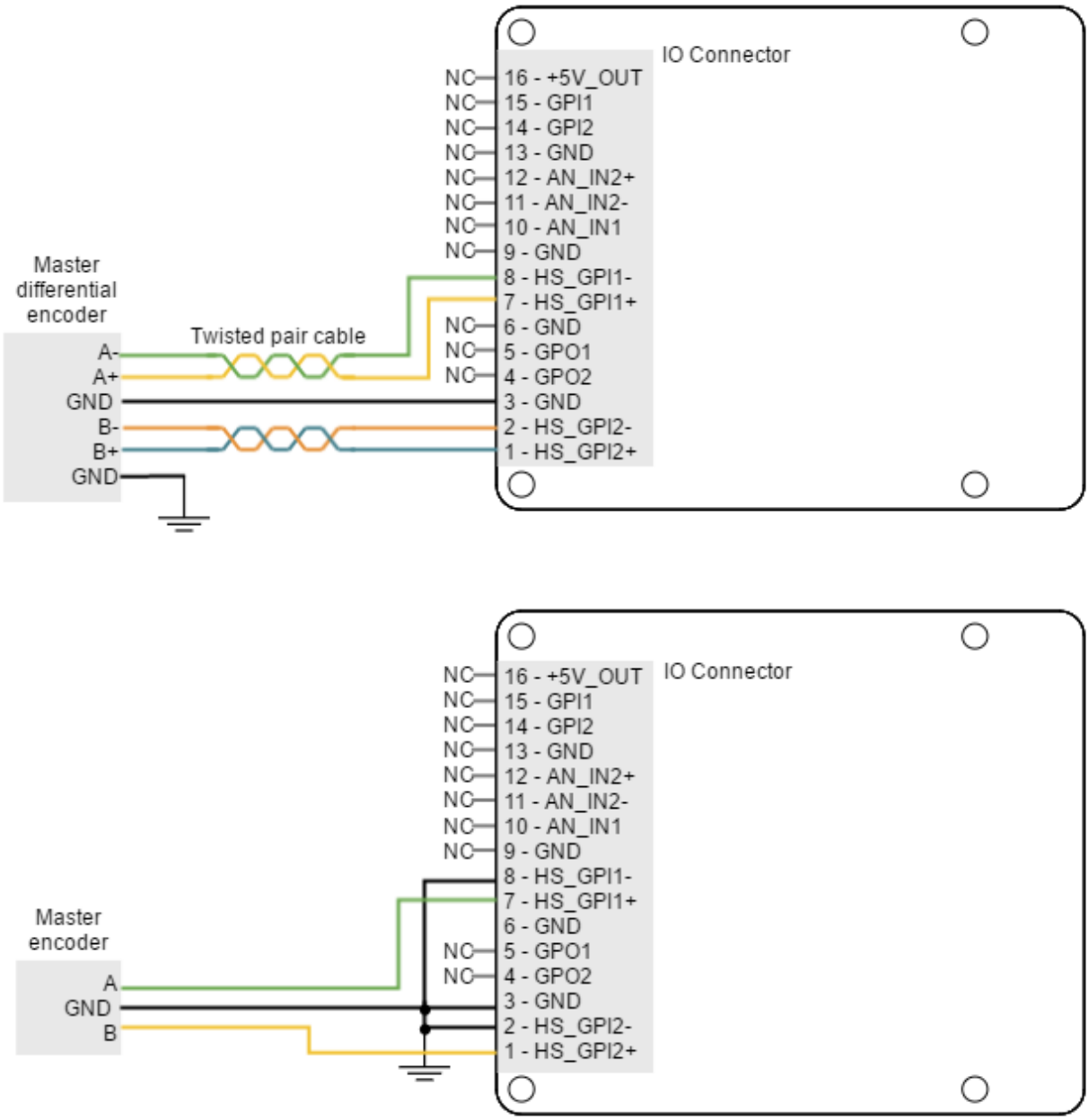




6.6.6 Encoder following or electronic gearing

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 Hydra 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:



6.7 Communications

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

- USB
- Serial interface - RS485
- CANopen

All the interfaces can be used to connect the Hydra 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.

6.7.1 USB interface

Hydra 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.

USB powered drive

The Hydra can be powered from USB for configuration purposes without the need of an external power supply. With USB supply the Hydra 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.

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 Hydra.
- Do not rely on an earthed PC to provide the Hydra 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.

6.7.2 RS485 interface

Hydra Servo Drive supports **full duplex RS-485**. This means that independent differential lines are used for TX and RX, which cannot be connected together. **Full-duplex RS485 is fully compatible with RS422 communication.**

Multi-point connection

Hydra Servo Drive RS485 interface is not intended for bus operation, since there is no collision prevention protocol implemented. However, **multiple drives can be connected to the same master using daisy chain connection**.

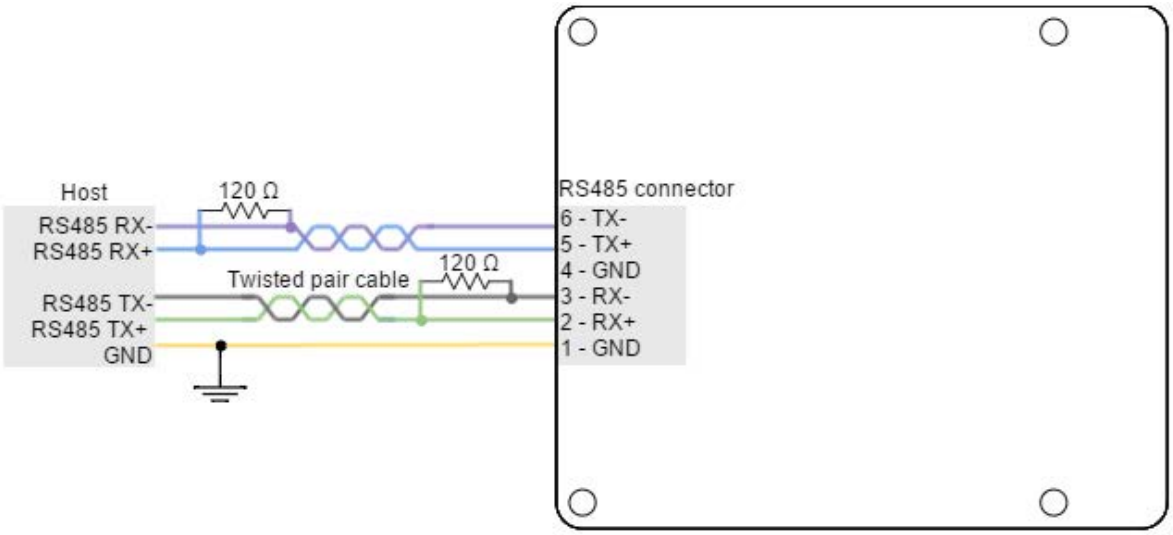
Multiple drive connection with daisy chain **must be configured using Ingenia** Motion Lab **suite.** Please, see UART configuration section in E-Core documentation for further information.

Main specifications of Hydra RS485 interface are shown in the next table:

Specification	Details
Interface	Full duplex Non-isolated Self-supplied (no need for external supply)
Communication distance	Up to 1200 m
Baud rate	100 kbps to 10 Mbps
Daisy chain	Supported

Termination resistor	Not included on board.

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



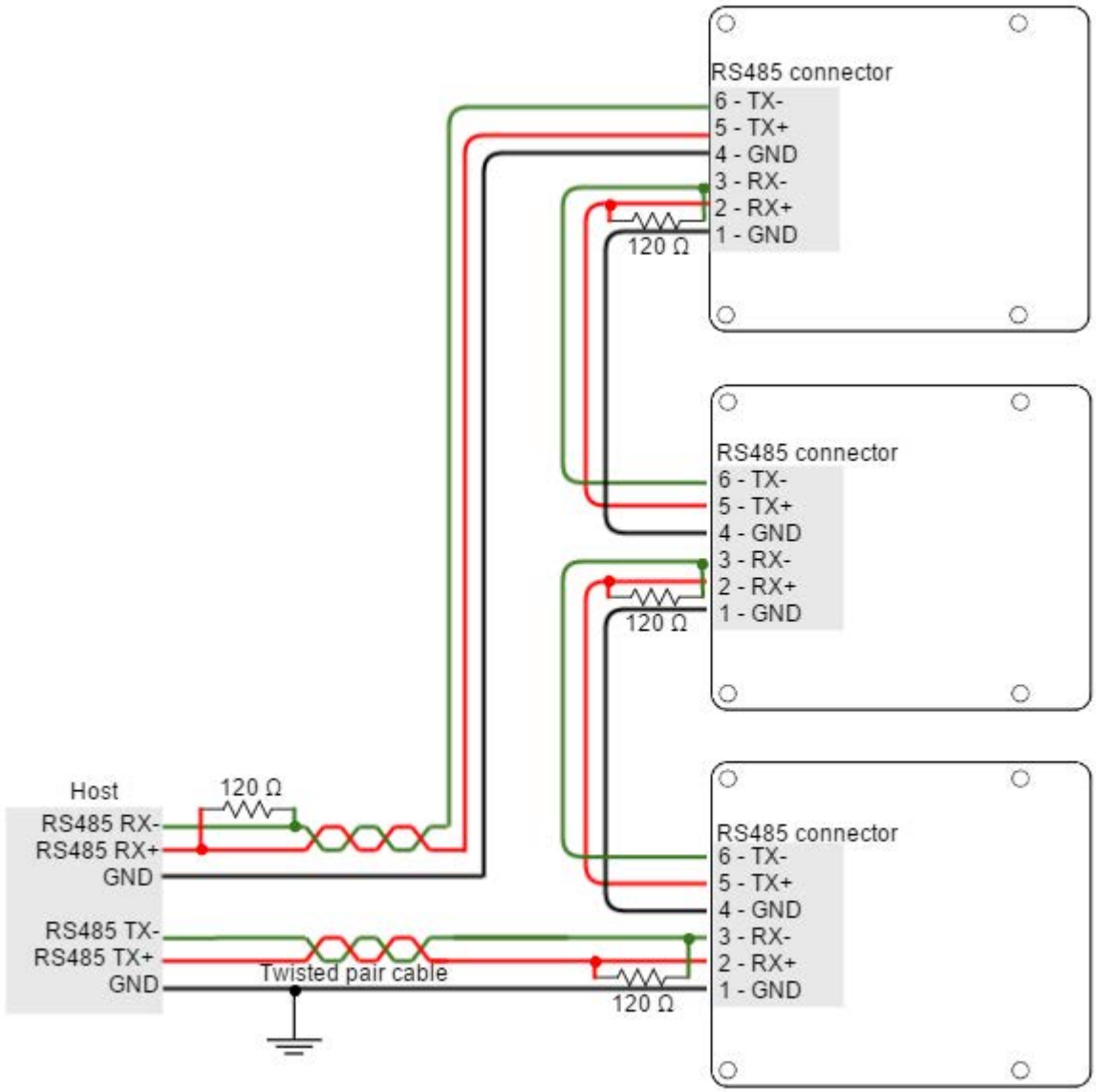
Termination resistor

The use of **termination resistors at the RX side** of each differential pair (120 Ω between RX+ and RX- of both host and slave) is essential for correct operation of the RS485 communication. **For long cable distances (> 10 m) a termination in the TX side** is also recommended.

Suggested termination resistor: Xicon 271-120-RC.

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 terminals of each device to the RX terminals of the next device. An example of daisy chain wiring of multiple Hydra is shown in the next figure.



Termination resistor for daisy chain

In daisy chain connection, **termination resistors are required in each link**. For short distances, a 120 Ω termination resistor in the RX side is required. For long distances (> 10 m) a termination is required in RX and TX sides.

6.7.3 CANopen interface

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

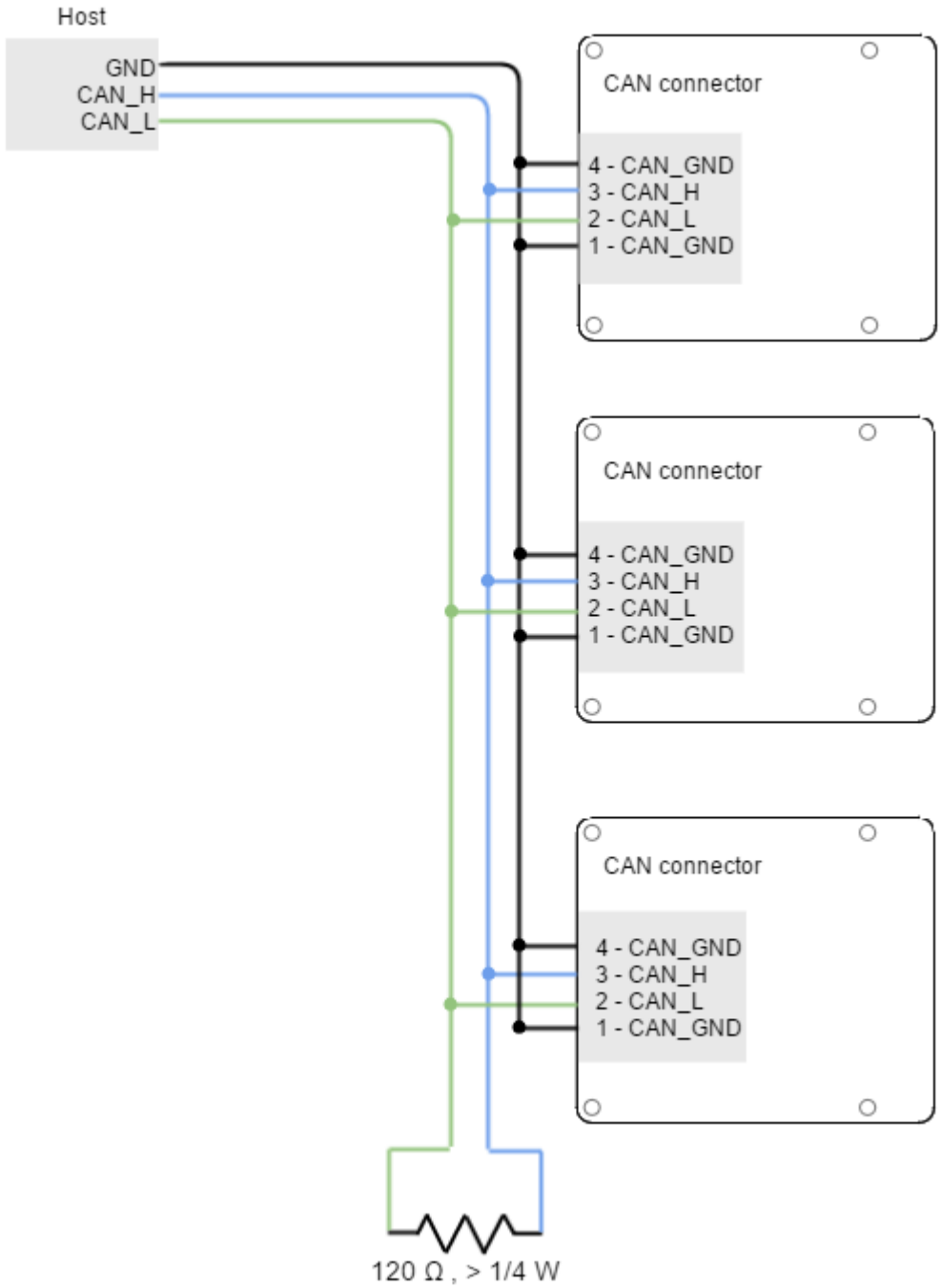
Specification	Details
Interface	Non-isolated Self-supplied (no need for external supply)
Baud rate	From 125 kbps to 1 Mbps (default value)
Maximum number of nodes	64
Common mode voltage	Up to 48 V

Termination resistor	120 Ω on board (mount jumper to enable the termination)

Drive ID

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

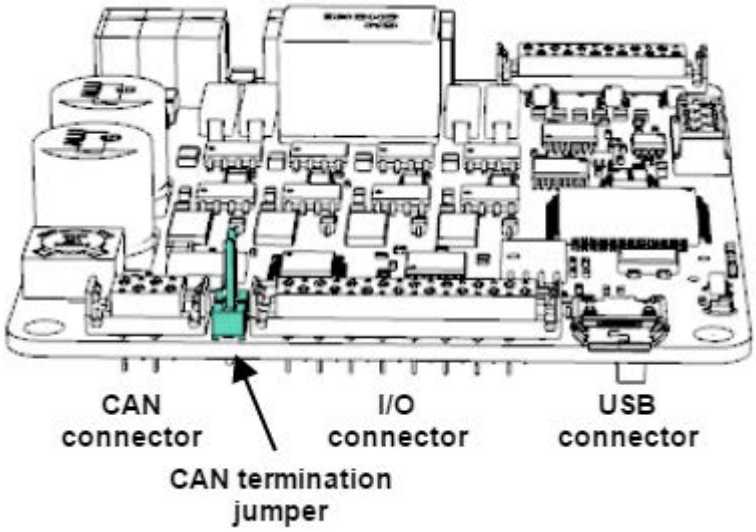
An example of CAN wiring is shown in the next figure.



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 Hydra connected, mount the termination resistor to ensure CAN bus operation. **Do not use wirewound resistors**, which are inductive.

Hydra Servo Drive includes a termination resistor on board. A jumper placed next to the CAN connector allows the user to connect or disconnect the 120 Ω termination resistor. Use a standard 1.27 mm pitch jumper for this purpose.



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 Hydra 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.

CAN interface for PC

The Ingenia Motion Lab suite is able to communicate with the Hydra 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.

Some recommended CAN transceivers are shown below:

Manufacturer	Part Number	Image	Description
Lawicel	CANUSB		• USB to CAN single channel interface with 9-pin D-SUB CAN connector. • Enables simple connection to CAN networks through COM port.

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.

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.

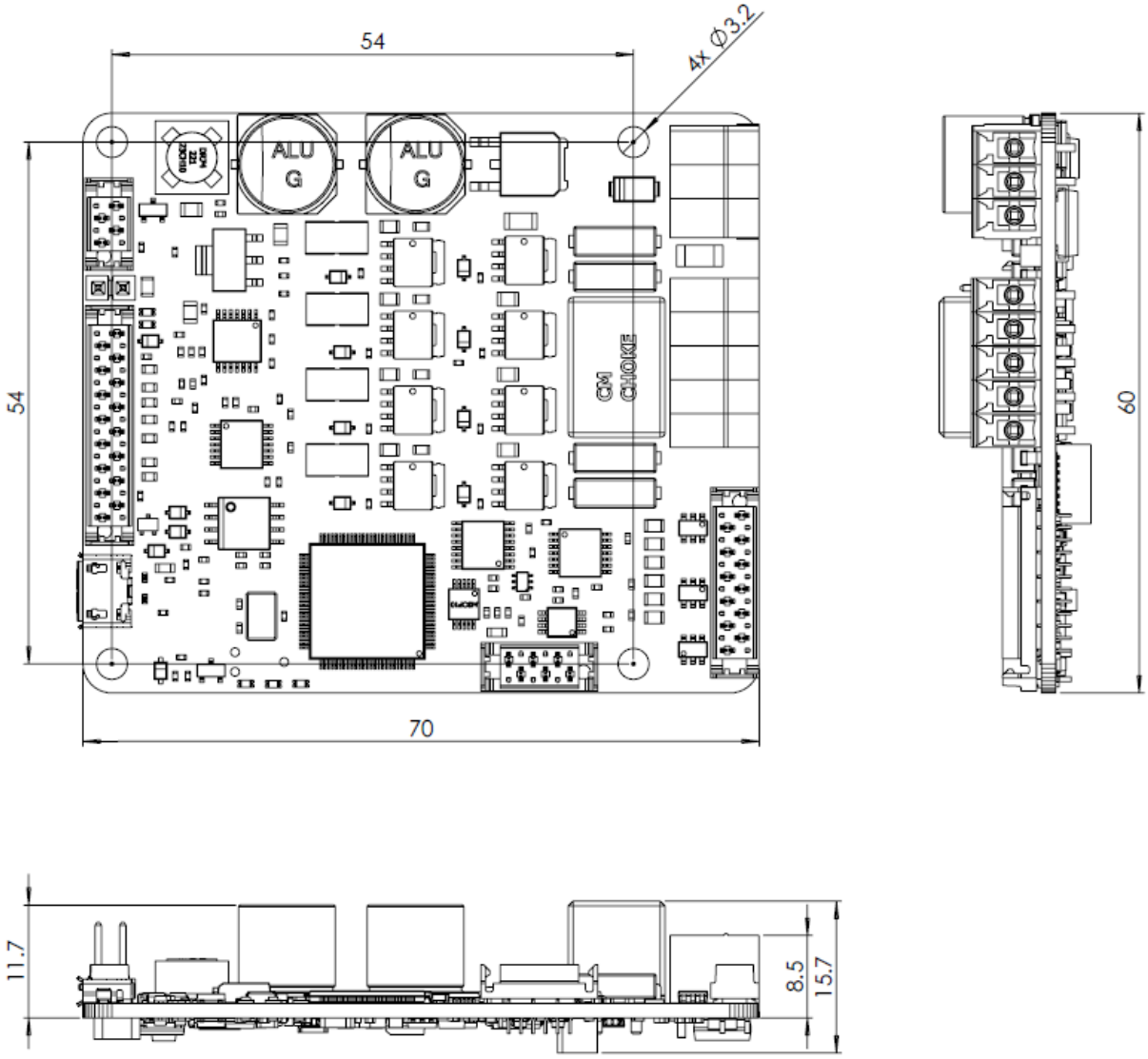
7 Dimensions

All the available version of Hydra Servo Drive present the same dimensions.

> **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.

Hydra Servo Drive has a 60 mm x 70 mm footprint and a maximum 15.7 mm height. he drive is provided with 4 x Ø 3.2 mm holes for M3 standoff mounting to the drive plate and to allow mounting the EtherCAT Daughter Board and the IO Starter Kit. These holes are plated and connected to protective earth (PE). 3D models can be downloaded here.

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



8 Software

8.1 Configuration

To connect, configure, tune your motor or upgrade the firmware of the Hydra, 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.

8.2 Applications

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

8.3 Arduino

To start an Arduino based project easily, connect using the serial RS485 port of the Hydra and use our Arduino Library Ardulib.