



INGENIA

Hydra Servo Drive Product Manual

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1 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	

2 Preliminary notes

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

This document applies to Hydra Servo Drive controller in its hardware revision 1.0.0R.

Please refer to [Hardware revisions](#) for information on previous hardware revisions and changes.

3 Safety information

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.

3.1 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).

3.2 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 75°C 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 10 V_{DC} to 48 V_{DC} 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.

4 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 needlessness 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.

4.1 Hydra part numbering

HYD-x/xx-y

Power rating:

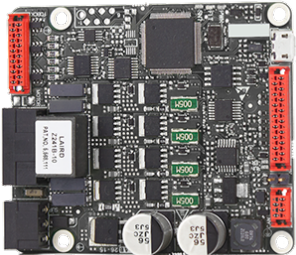
8/48 = 8 A cont / 16 A peak @ 48 V nominal

4/48 = 4 A cont / 8 A peak @ 48 V nominal

Communication interfaces:

S = USB/RS-485

C = USB/RS-485/CANopen

Orderable part number	Status	Image
HYD-4/48-S	ACTIVE	
HYD-4/48-C	ACTIVE	
HYD-8/48-S	ACTIVE	
HYD-8/48-C	ACTIVE	

4.2 Specifications

The Hydra Servo Drive specs are shown next.

Electrical and power specifications		
	HYD-4/48-y	HYD-8/48-y
Power supply voltage	12 V _{DC} to 48 V _{DC}	
Transient peak voltage	60 V	

Electrical and power specifications	
Internal DC bus capacitance	112 μ F
Minimum motor inductance	300 μ H
Maximum phase peak current	8 A_{RMS} (5 s) 16 A_{RMS} (5 s)
Maximum phase continuous current	4 A_{RMS} 8 A_{RMS}
Current sense range	± 32 A ± 16 A
Current sense resolution	62.32 mA/count 31.16 mA/count
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	<ul style="list-style-type: none"> 2 phases bipolar stepper
Power stage PWM frequency	40 kHz (default) 80 kHz (high PWM frequency, configurable)
Current sensing	On phases A, B and C using 3 terminal shunt resistors. Accuracy is $\pm 1\%$ full scale. 10 bit ADC resolution.
Sensors for commutation	<ul style="list-style-type: none"> Quad. Incremental encoder
Sensors supported for servo loops	<ul style="list-style-type: none"> Quad. Incremental encoder

Electrical and power specifications

Supported target sources

- Network communication – **USB** (μUSB connector)
- Network communication – **CANopen** (CiA-301, CiA-303, CiA-305, CiA-306 and CiA-402 compliant)
- Network communication – **RS-485** (Single or multiple)
- **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. GDI1, GDI2 (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. (1 A short-circuit and over-current rugged)

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 & EMI protections: ESD protections are available in all inputs, outputs and communications. All inputs, outputs, feedbacks include noise filters.
- Inverse polarity supply protection (bidirectional)
- High power transient voltage suppressor for short braking: A TVS diode (1500 W peak) protects the circuitry from the voltage transients events
- Encoder broken wire (for differential quadrature encoders only).

Communications

Electrical and power specifications	
USB	µUSB (2.0) connector. The board can be supplied from USB for configuration purposes.
Serial	RS485 non-isolated.
CANopen	Yes, non-isolated. Includes jumper to enable 120 Ω termination.
EtherCAT	Option.
Environmental and mechanical specifications	
Ambient air temperature	<ul style="list-style-type: none"> • -40 °C to +50 °C full current (operating) • +50 °C to +100 °C current derating (operating) • -40 °C to +125 °C (storage)
Maximum humidity	5% - 85% (non-condensing)
Dimensions	60 mm x 70 mm x 15.7 mm
Weight (exc. mating connectors)	35 g

4.3 Hardware revisions

Hardware revision*	Description and changes
1.0.0	First product release.

*Hardware revision is screen printed in white below motor connector, on the bottom of the Hydra.

4.4 Power and current ratings

4.4.1 The Hydra is capable of providing the nominal current from -10°C to 50°C ambient air temperature without the need of any additional heatsink. From 50°C to 80°C of ambient temperature a current derating is needed.

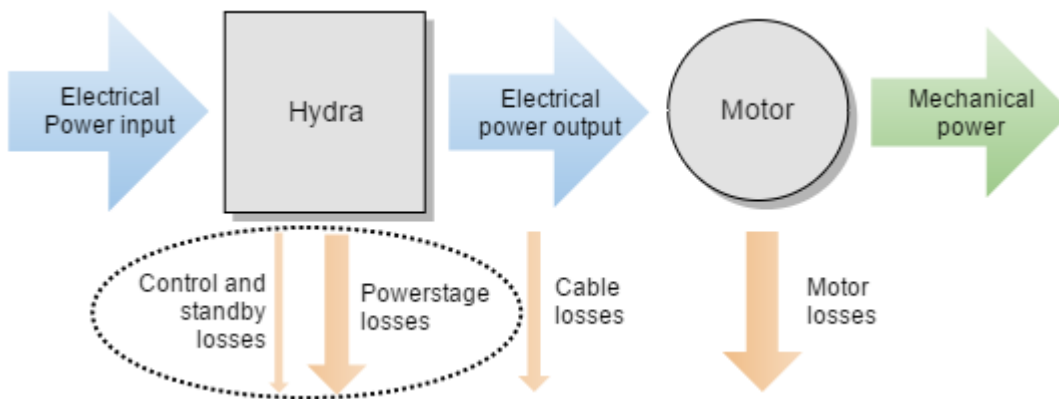
Excessive power losses lead to over temperature that will be detected and cause a the driver to turn off. The system temperature is available in [EMCL registers](#) and is measured on the power stage. The temperature parameter that can be accessed from USB 2.0, CAN or RS485 interface does not indicate the air temperature. Above 110°C 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

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

Future [versions of firmware](#) will allow an automatic current fold-back based on temperature. This means the current will be reduced before an over-temperature occurs. Stay tuned for upgrades!

⚠ Some parts of the Hydra exceed 110°C when operating, especially at high load levels. **Do not touch the driver when operating** and wait at least 5 minutes after turn off to allow a safe cool down.



4.4.2 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:

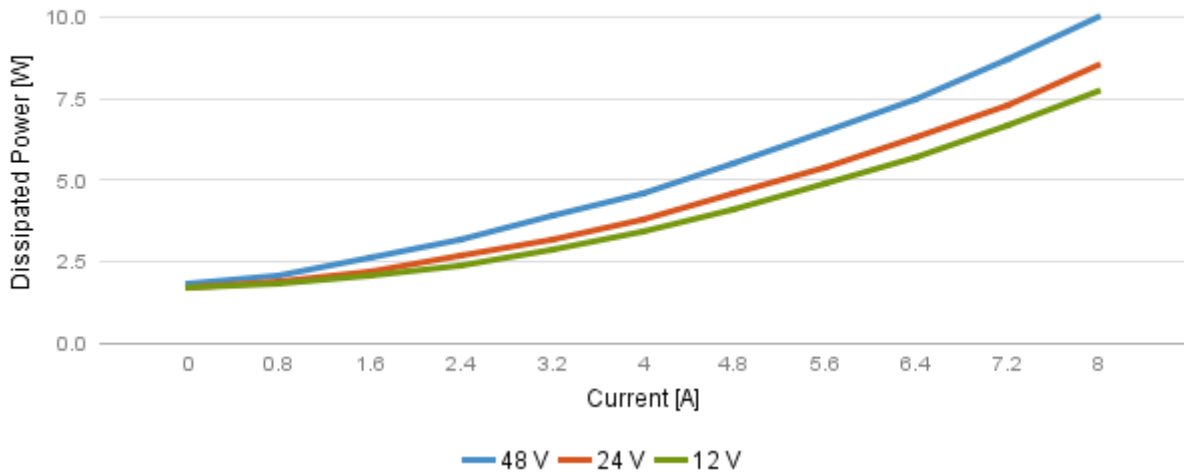
- **Motor RMS current:** positive correlation.
- **DC bus voltage:** positive correlation.

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.

Power dissipation versus motor current at different voltages for HYD-48V-8A



4.4.3 Current ratings

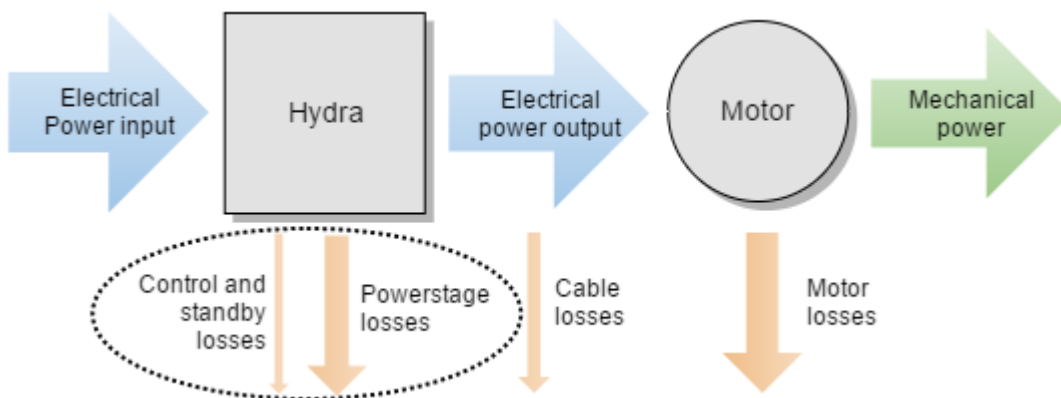
The Hydra Servo drive has no cold plate, so the board itself is the heatsink. Power losses cause the driver to increase its temperature following the this formula:

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

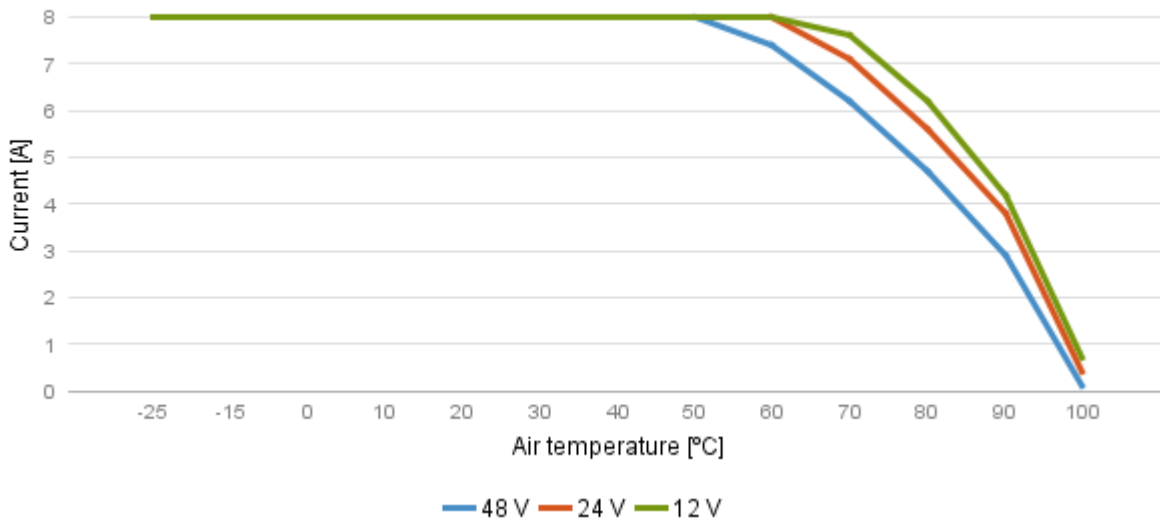
Since $T_p < 110^\circ\text{C}$ for safe operation, the maximum current rating can be calculated.

The thermal impedance typical value is shown above, however its exact value will vary according to:

- Air flow around the driver.
- Position (vertical allows natural convection).



Maximum current ratings at different voltages for HYD-48V-8A



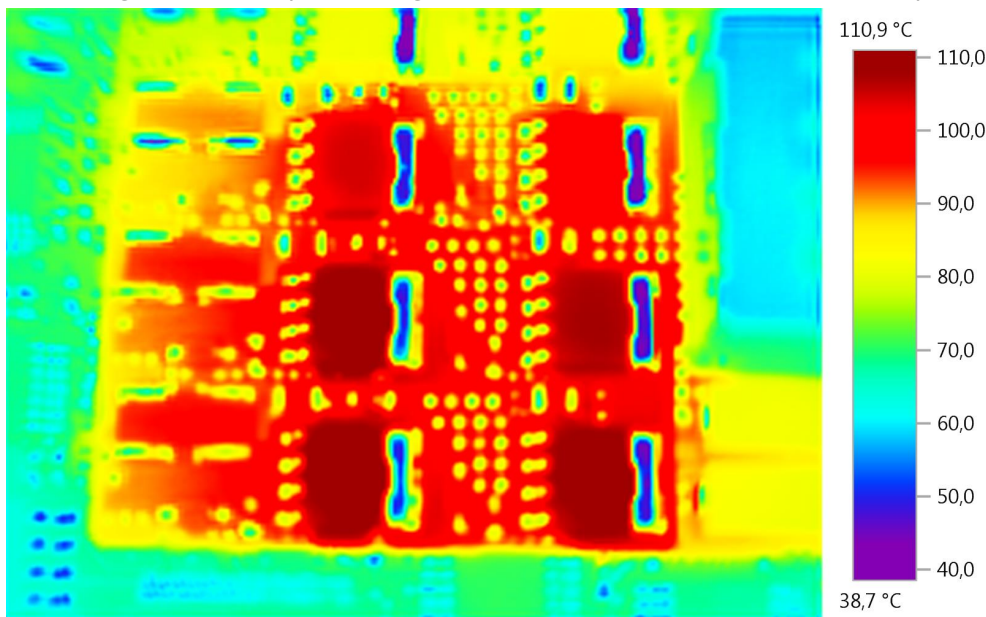
✔ Current derating

The current derating graph is 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.

4.4.4 System temperature

The system temperature is measured near the power stage. Between power phases. The temperature parameter that can be accessed from USB 2.0 or CAN bus indicates the board temperature (not the air temperature) and should not exceed 110°C. Above 110°C the Hydra automatically turns off the power stage and stays in fault state avoiding any damage to the drive.

Next images show the power stage surface at maximum load and air temperature in a 3 phase application.



i The driver 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.

4.4.5 Dynamic application (non-constant current)

The Hydra has a big thermal inertia that allows storing heat during short current pulses (exceeding nominal current) without causing an over temperature.

This allows achieving high peak current ratings without need of additional heatsink.

Easy approach (quadratic mean of current)

For most systems where the cycle time is shorter than 3τ (thermal time constant) the 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:

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

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

T: Full cycle period.

I_1 : Current during t_1

I_2 : Current during t_2

I_n : Current during t_n

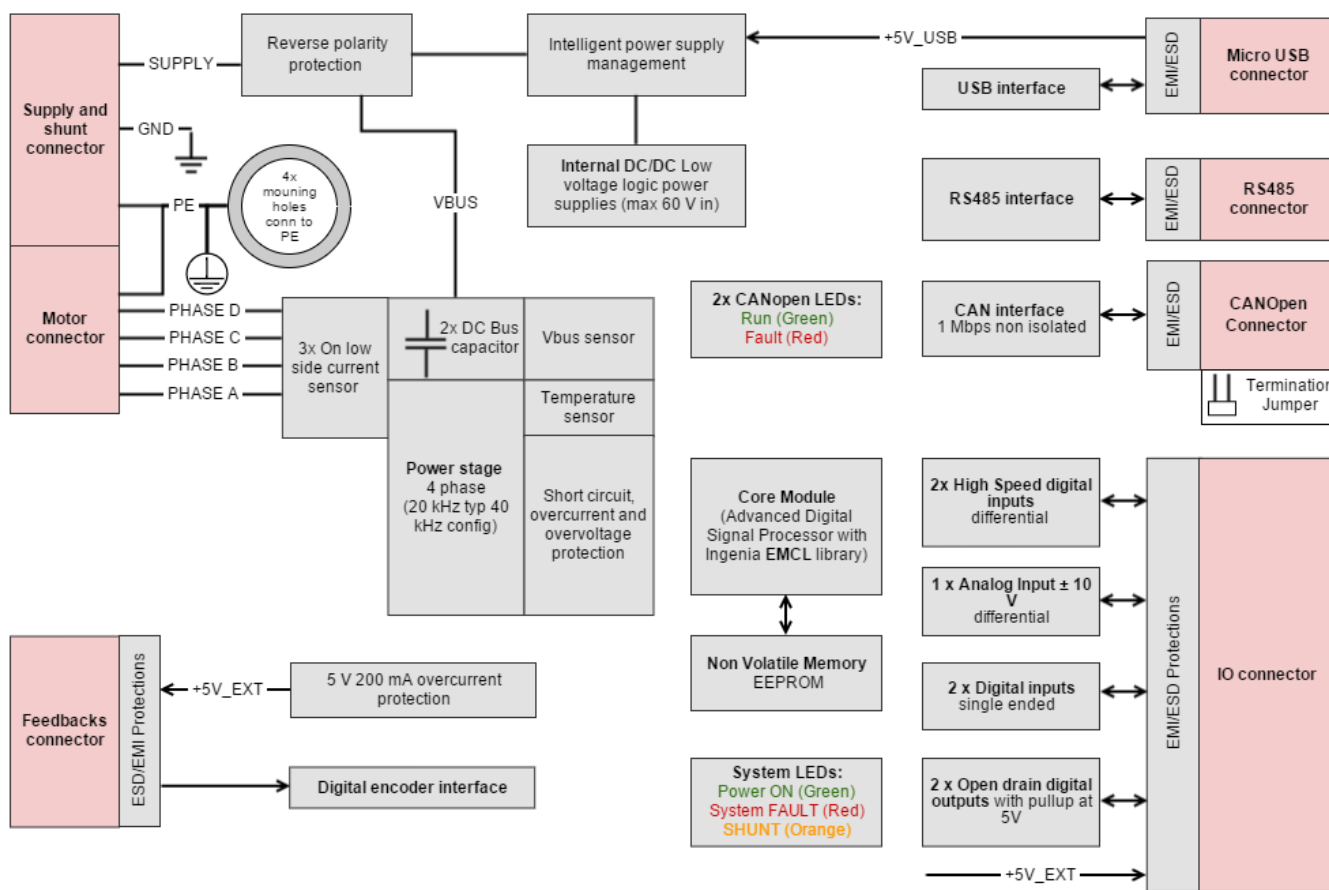
Dynamic model

For systems with a time $>$ than 3τ the dynamic model should be used.

Instead of considering thermal resistances you should consider the thermal impedance. The Hydra model can be simplified as a 2nd order.

4.5 Architecture

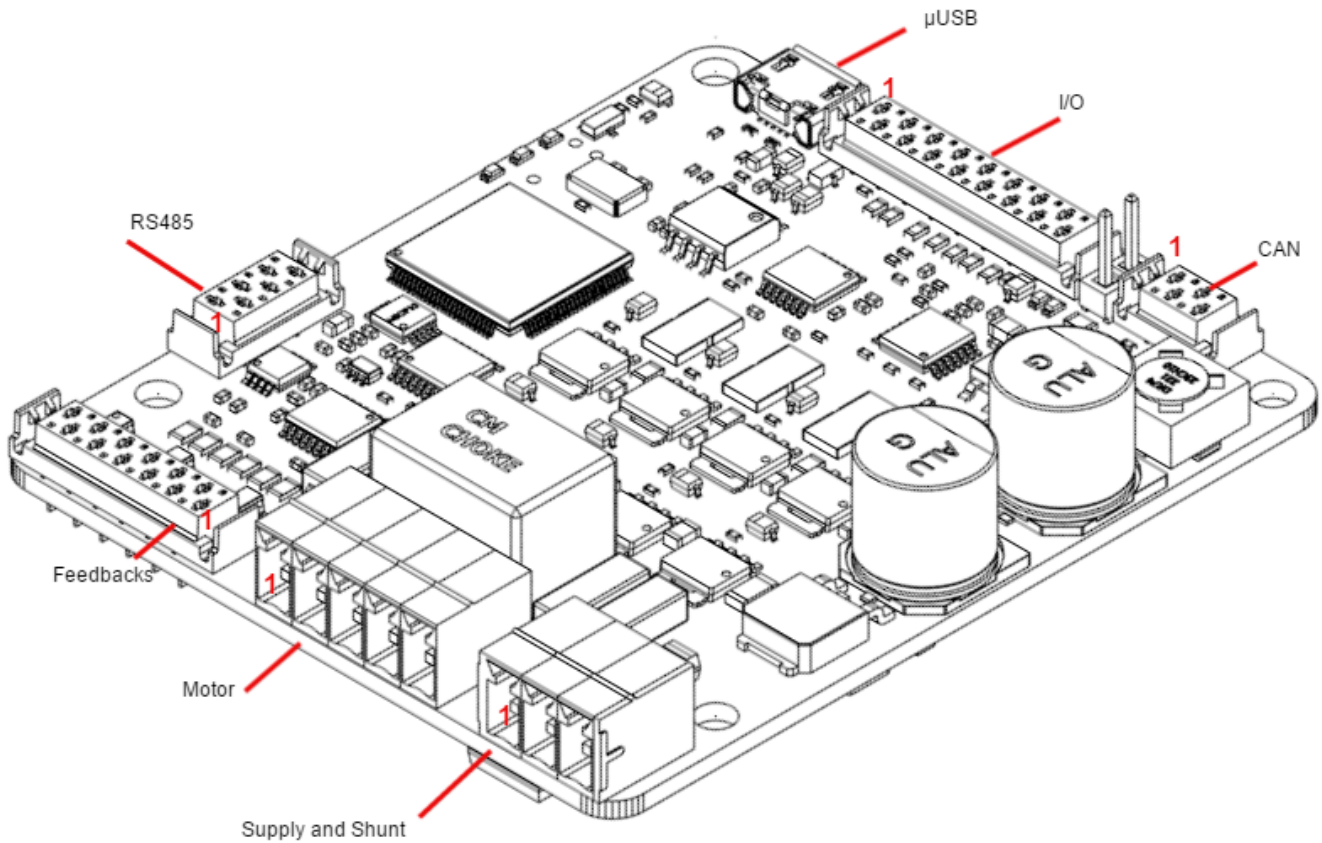
Following figure shows a simplified hardware architecture of the Hydra Servo Drive. Links provide direct access to relevant pages.

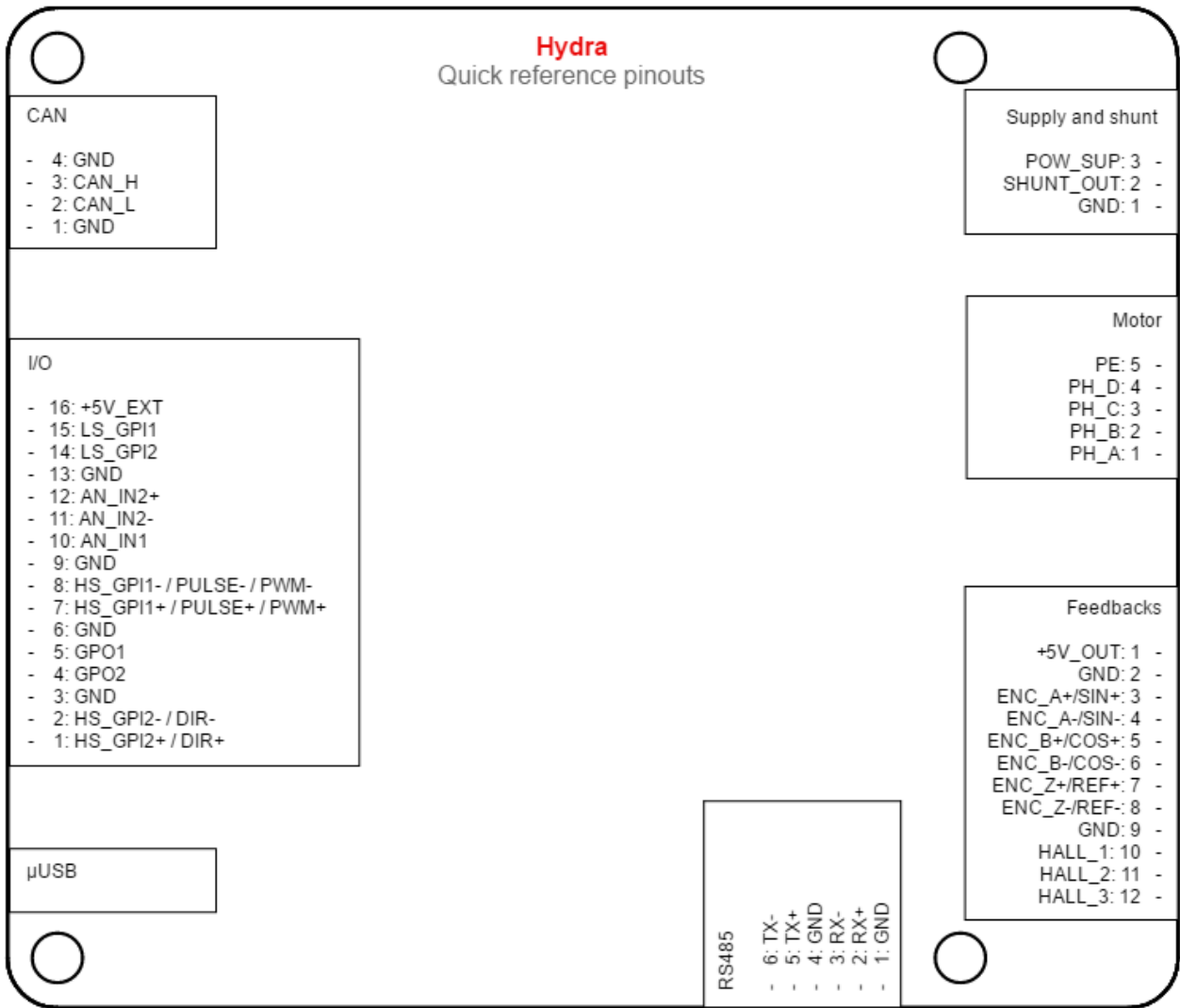


5 Connectors

5.1 Connectors position and pinout

Next Figures show Hydra Servo Drive connectors. Connector functionalities and pinouts are described in detail in the next subchapters. For EtherCAT connectors pinout see [below](#).

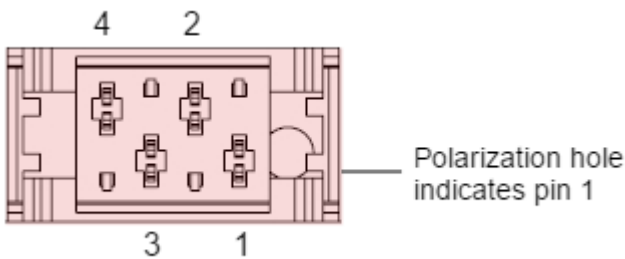




5.1.1 CAN interface connector

The [CAN interface](#) connector is a 4 pin TE Micro-Match connector. Part number [338068-4](#). Polarization hole on PCB indicates pin 1 and ensures correct mating connector position.

Pin numbers and pinout are shown below.



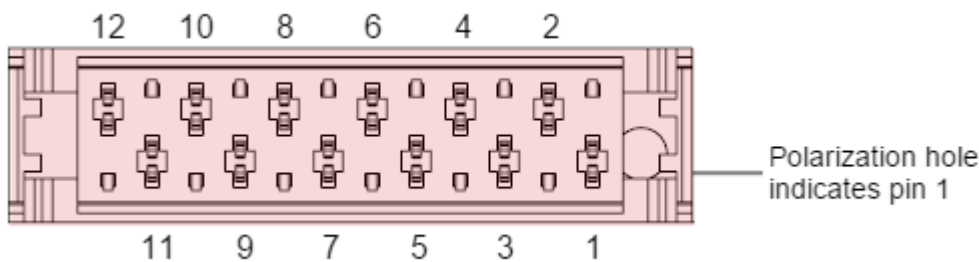
Pin	Name	Description
1	GND	Ground
2	CANL	CAN bus line dominant low

Pin	Name	Description
3	CANH	CAN bus line dominant high
4	GND	Ground

5.1.2 Feedbacks connector

Hydra has a 12 pin TE Micro-Match connector for motor feedbacks. Part number [TE 1-338068-2](#). Polarization hole on PCB indicates pin 1 and ensures correct cable position. See [Feedback connections](#) for more information about different feedbacks wiring.

Pin numbers and connector's pinout are shown below.

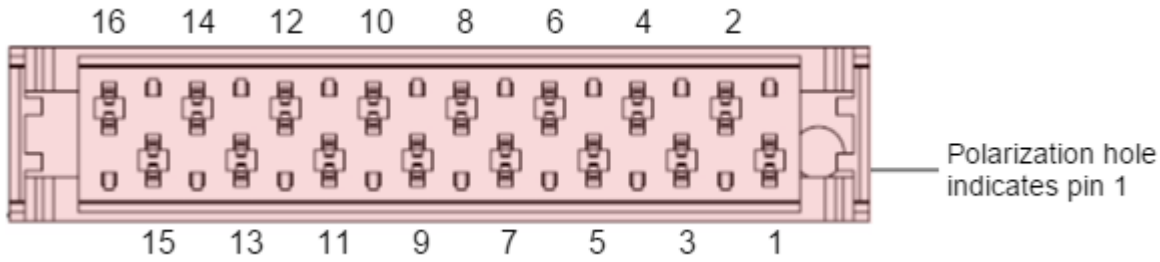


Pin	Name	Description
1	+5V_OUT	5 V @ 250mA supply for feedbacks
2	GND	Ground connection
3	ENC_A+	Single ended digital encoder: A input Differential digital encoder: A+ input
4	ENC_A-	Differential Encoder: A- input
5	ENC_B+	Single ended digital encoder: B input Differential digital encoder: B+ input
6	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


5.1.3 I/O connector

Hydra has a 16 pin TE Micro-Match connector for inputs and outputs. Part number [1-338068-6](#). Polarization hole on PCB indicates pin 1 and ensures correct cable position.

Pin numbers and connectors pinout are shown below.



Pin	Name	Description
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
5	GPO1	Digital output 1
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	LS_GPI2	Low speed digital single ended input 2
15	LS_GPI1	Low speed digital single ended input 1
16	+5V_EXT ¹	+5V 200mA max output (shared with feedback connector)

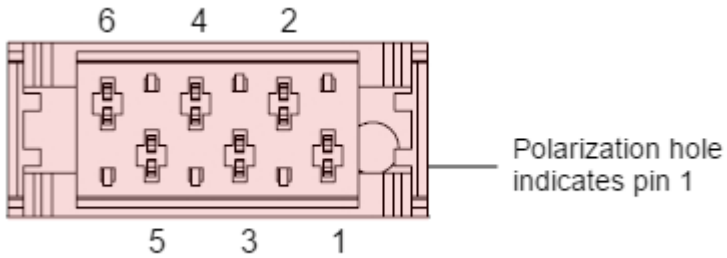
 The connector pinout is identical as in Pluto Servo drive. See: [Cable Kit Manual](#).

- ✓ I/O connector pinout is shared with [Jupiter](#), [Pluto](#), [Nix](#) and [Neptune](#) servo drives, which allows using the [IO starter kit](#) with Hydra.

5.1.4 RS485 interface connector

The [RS485 interface](#) connector is a 6 pin TE Micro-Match connector. Part number [338068-6](#). Polarization hole on PCB indicates pin 1 and ensures correct cable position.

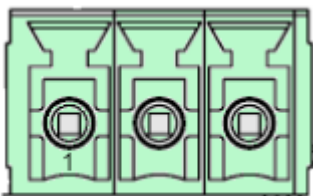
Pin numbers and connector pinout are shown below:



Pin	Name	Description
1	GND	Common (internally connected to driver 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 driver GND)
5	TX+	RS485 transmit data + (should be connected to master RX+)
6	TX-	RS485 transmit data - (should be connected to master RX-)

5.1.5 Supply and shunt connector

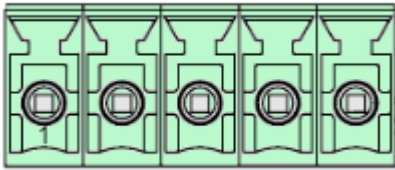
The supply and shunt connector is a 3 pin FCI pluggable terminal block with 3.5 mm pitch. Part number [20020110-C031A01LF](#). Pin numbers and connectors pinout are shown below.



Pin	Name	Description
1	GND	Negative power supply input (Ground)
2	SHUNT_OUT	External shunt resistor connection
3	SUP +	Positive power supply input

5.1.6 Motor connector

The motor connector is a 5 pin FCI pluggable terminal block with 3.5 mm pitch. Part number [20020110-C051A01LF](#). Pin numbers and connectors pinout are shown below.



Pin	Name	Description
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

5.1.7 USB interface connector

Hydra includes a 5 pin micro-USB connector for USB interface. This allows easy access to the driver configuration using [MotionLab Documentation Home](#) or downloading [firmware upgrades](#). Please see [USB interface](#) page for further information.

Pin numbers and standard pinout are shown below:



Pin	Name	Description
1	USB_SUPPLY	USB +5 V supply input.
2	USB D-	USB Data- line
3	USB D+	USB Data+ line
4	NC	Not connected
5	GND	Ground
SHIELD	NC	Not Connected (Connector metallic shield)

5.2 Mating connectors

5.2.1 CAN interface mating connector

For flat ribbon cable

The easiest and lowest cost option is using a flat ribbon cable with 1.27 mm pitch.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	215083-4	2399655	A107032TR-ND	571-215083-4
Suggested cable	3M	HF365/04SF	2396432	MD04R-100-ND	517-HF365/04SF

i Wire impedance

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 .

For multi-core crimped cable

Some applications require single cables with crimp terminals. This makes the wiring cleaner and is a preferred option for volume applications. Jupiter connectors include locking latches that provide audible click during mating and ensure assembly robustness.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	338095-4	2420421	-	571-338095-4
Crimp terminals	TE Connectivity	1-338097-1	1291807	A99491CT-ND	571-1-338097-1
Suggested cable	Use 0.2 ~ 0.5 mm ² (20 ~24 AWG) twisted pair with 120 Ω differential impedance.				

Cleverly wiring CAN buses from standard DB9 connectors

The Jupiter 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:

Jupiter Micro-Match	DB9 standard to ribbon cable
1 (GND)	6 (GND)
2 (CANL)	2 (CANL)
3 (CANH)	7 (CANH)
4 (GND)	3 (GND)

5.2.2 Feedbacks mating connectors

For ribbon cable

The easiest and lowest cost option is using a flat ribbon cable with 1.27 mm pitch. Please see [Pluto feedbacks cable](#).

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	8-215083-2	149093	A99460CT-ND	571-8-215083-2
Suggested cable	3M	3302/16 300SF	1369751	MC16M-300-ND	517-C3302/16SF



Multi-core crimped cable

Some applications require single cables with crimp terminals. This makes the wiring cleaner and is a preferred option for volume applications. Jupiter connectors include locking latches that provide audible click during mating and ensure assembly robustness.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	1-338095-2	-	A99497-ND	571-1-338095-2
Crimp terminals	TE Connectivity	1-338097-1	1291807	A99491CT-ND	571-1-338097-1
Suggested cable	Use 0.2 ~ 0.5 mm ² (20 ~24 AWG) flexible wires.				



5.2.3 RS485 mating connectors

For flat ribbon cable

The easiest and lowest cost option is using a flat ribbon cable with 1.27 mm pitch.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	215083-8	149184	A99462CT-ND	215083-8
Suggested cable	3M	HF365/06SF	1859550	MD06R-100-ND	517-HF365/06SF

For crimped cable

Some applications require single cables with crimp terminals. This makes the wiring cleaner and is a preferred option for volume applications. Jupiter connectors include locking latches that provide audible click during mating and ensure assembly robustness.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	338095-6	-	A99415-ND	571-338095-8
Crimp terminals	TE Connectivity	1-338097-1	1291807	A99491CT-ND	571-1-338097-1
Suggested cable	Use 0.2 ~ 0.5 mm ² (20 ~24 AWG).				

5.2.4 I/O mating connectors

For ribbon cable

The easiest and lowest cost option is using a 16 way flat ribbon cable with 1.27 mm pitch. Please see [Pluto feedbacks cable](#).

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	8-215083-6	149147	A99458CT-ND	571-8-215083-6
Suggested cable	3M	3302/16 300SF	1369751	MC16M-300-ND	517-C3302/16SF



Multi-core crimped cable

Some applications require single cables with crimp terminals. This makes the wiring cleaner and is a preferred option for volume applications. Jupiter connectors include locking latches that provide audible click during mating and ensure assembly robustness.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	TE Connectivity	1-338095-6	-	A99495-ND	571-1-338095-6
Crimp terminals	TE Connectivity	1-338097-1	1291807	A99491CT-ND	571-1-338097-1
Suggested cable	Use 0.2 ~ 0.5 mm ² (20 ~24 AWG) flexible wires.				



5.2.5 Supply and shunt mating connector

This pluggable terminal block mating connector provides an easy installation and connection.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	Phoenix Contact	1840379	5088963	277-2413-ND	651-1840379



i Wire gauges

Dimension the wiring according to the application current ratings. Higher section is preferred to minimize resistance and wire self-heating. Recommended wire section is 0.5 mm² ~ 1.5 mm².

5.2.6 Motor mating connector

This pluggable terminal block mating connector provides an easy installation and connection.

	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Connector	Phoenix Contact	1840395	5088987	277-5721-ND	651-1840395



i Wire gauges

Dimension the wiring according to the application current ratings. Higher section is preferred to minimize resistance and wire self-heating. Recommended wire section is 0.5 mm² ~ 1.5 mm².

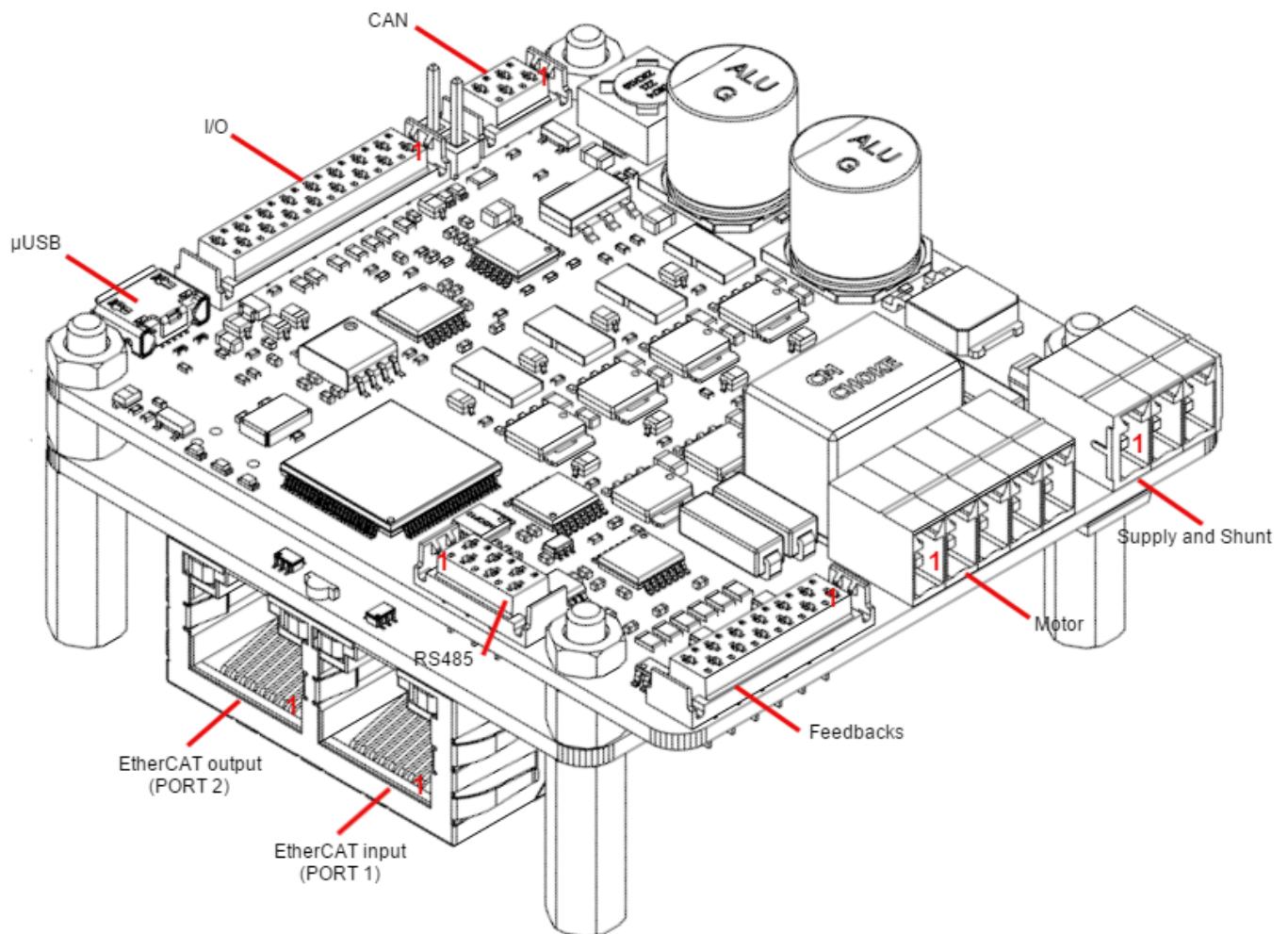
5.2.7 USB mating connector

USB 2.0 A to micro-B (as used in mobile phones chargers) are valid for interfacing the Jupiter. Following are suggested part numbers.

Connector	Manufacturer	Manufacturer ID	Farnell	Digikey	Mouser
Micro USB 2.0 cable assembly	Molex	68784-0002	1617586	WM17146-ND	538-68784-0002

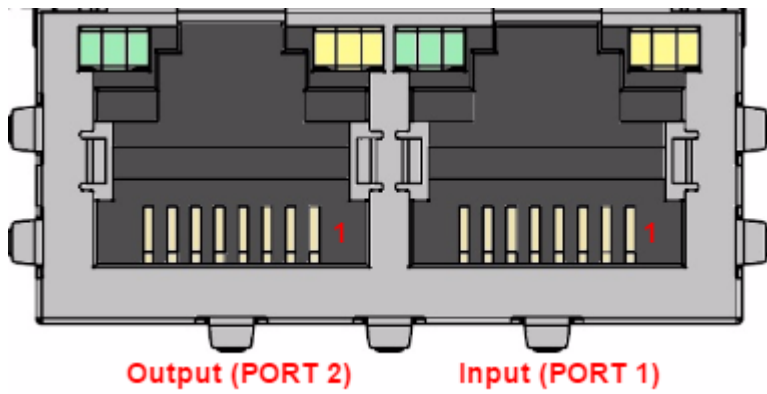
5.3 EtherCAT variant pinout

Next figure show Hydra Servo Drive EtherCAT variant. Connector functionalities and pinouts are described next.



5.3.1 EtherCAT input and output connector

Hydra EtherCAT variant includes 2 RJ45 ports for the EtherCAT communication, the input connector (PORT 1) and the output connector (PORT 2). The pinout is shown below.



EtherCAT input (PORT 1)

Pin	Name	Description
1	TX_D+	Transmit Data+ line
2	TX_D-	Transimt Data- line
3	RX_D+	Receive Data+ line
4	+2V5	2.5 V generated internally
5	+2V5	2.5 V generated internally
6	RX_D-	Receive Data- line
7	NC	Not connected
8	GND_CHASSIS	Connected to the connector chassis

EtherCAT output (PORT 2)

Pin	Name	Description
1	TX_D+	Transmit Data+ line
2	TX_D-	Transmit Data- line
3	RX_D+	Receive Data+ line
4	+2V5	2.5 V generated internally
5	+2V5	2.5 V generated internally
6	RX_D-	Receive Data- line
7	NC	Not connected
8	GND_CHASSIS	Connected to the connector chassis

6 Wiring and connections

Once the Hydra Servo Drive is mounted, the device can be wired. Proper wiring, grounding and shielding are essential for ensuring safe, immune and optimal servo performance of the drive.

Next pages show detailed connection recommendation as well as technical details of each interface.

- [Power supply wiring](#)
- [Motor output wiring](#)
- [Feedback connections](#)
- [IO connections](#)
- [Command sources](#)
- [Communications](#)

6.1 Power supply wiring

The Hydra has a single [Supply and shunt connector](#), and has a single power supply input (12 V_{DC} to 48 V_{DC}) for control and motor power. An internal power supply 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 driver is not capable of driving a motor or sensing a feedback input due to USB power limitations.

6.1.1 How to dimension the power supply


The choice of a power supply is determined by voltage, current and power supply type (switching versus linear, regulated versus unregulated...). Following are shown some guidelines to properly dimension the Hydra power supply:

- 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 for the peak of the application. This means 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.

 There is a special consideration if the power supply will be at or near the maximum voltage rating of the drive. If the motor will be rapidly decelerating a large inertial load from a high speed, care has to be taken to absorb the returned energy. In this case, the [Shunt resistor](#) should be used.

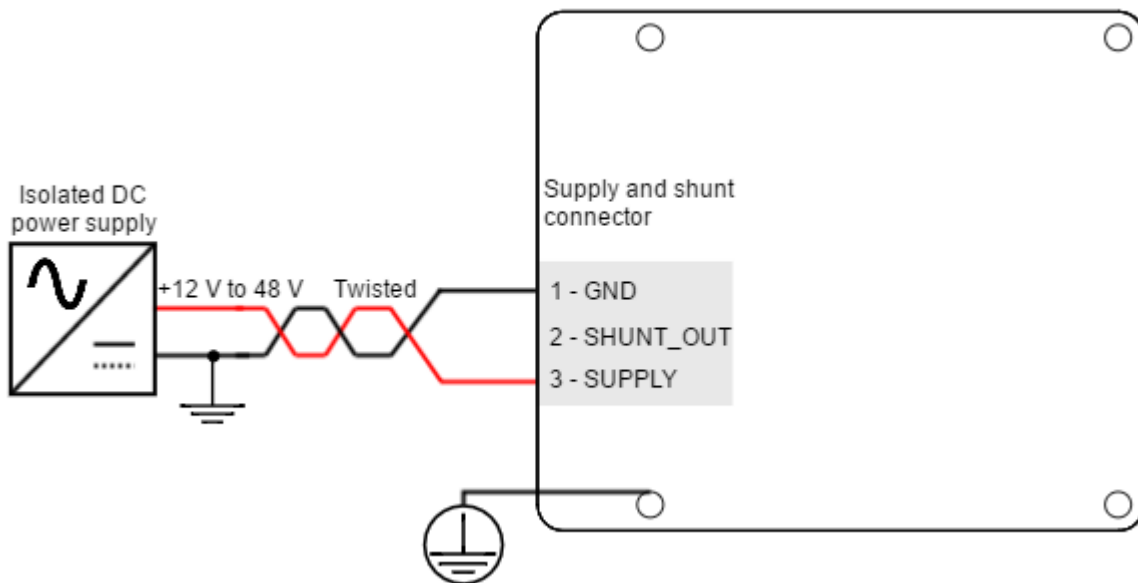
Following are shown different power supply recommendations:

Manufacturer	Part Number	Rated Voltage (V)	Rated Current (A)	Image	Description

Manufacturer	Part Number	Rated Voltage (V)	Rated Current (A)	Image	Description
TDK Lambda	PFE1000F48	48	21		Switching closed frame power supply, 1000 W

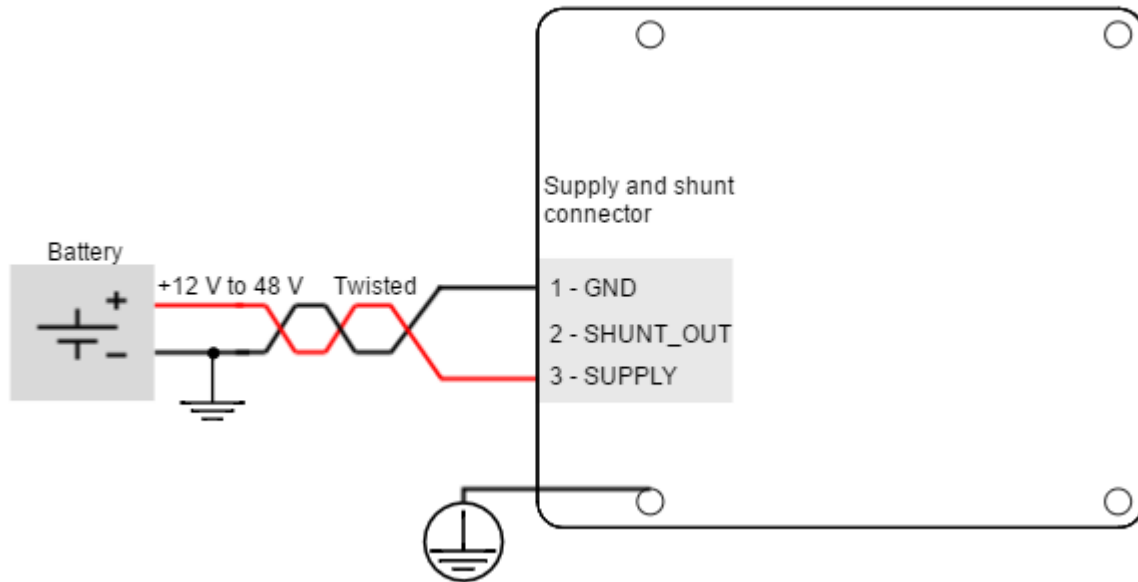
6.1.2 Recommended power supply connection

The recommended power supply connection is shown below. Twisted power supply cables are preferred to reduce electromagnetic emissions and increase immunity. Distance between line filter and Hydra Servo Drive should always be minimized.



6.1.3 Simplified battery supply connection

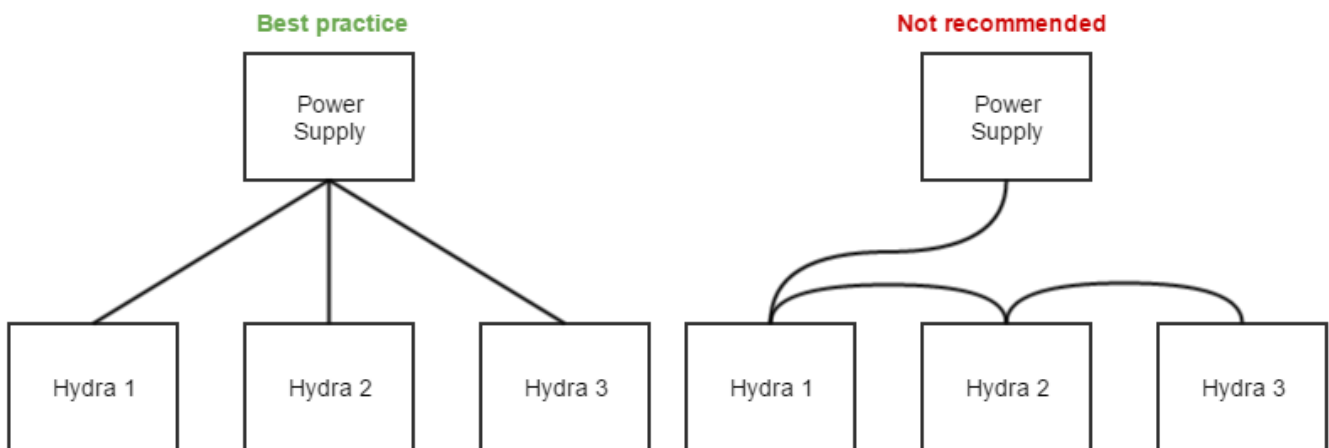
Next figure shows a simplified wiring diagram for the Hydra Servo Drive power supply from a battery.



⚠ 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.

6.1.4 Connection of multiple drivers

Always use "star" connections when different servo drivers are connected to the same power supply. Connect each drive to the common supply using separate wires for positive and return.



6.1.5 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 diameter should not exceed 3.5 mm (the connector pitch).

Connection	Minimum wire size	Maximum wire size
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Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	0.5 mm ²	1.5 mm ² (16 AWG)
Solid wire	0.5 mm ²	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. Due to the connector's size, the maximum allowed ferrule size is 0.5 mm². Ensure crimped ferrule diameter does not exceed 2 mm and the insulator is < 3.5 mm. For higher power applications, direct cable connection is recommended.

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 length, 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 power cables are preferred.

For best immunity use twisted and shielded 2-wire cables for the DC power supply. This becomes crucial in long cable applications.

Protective earth (PE) connection

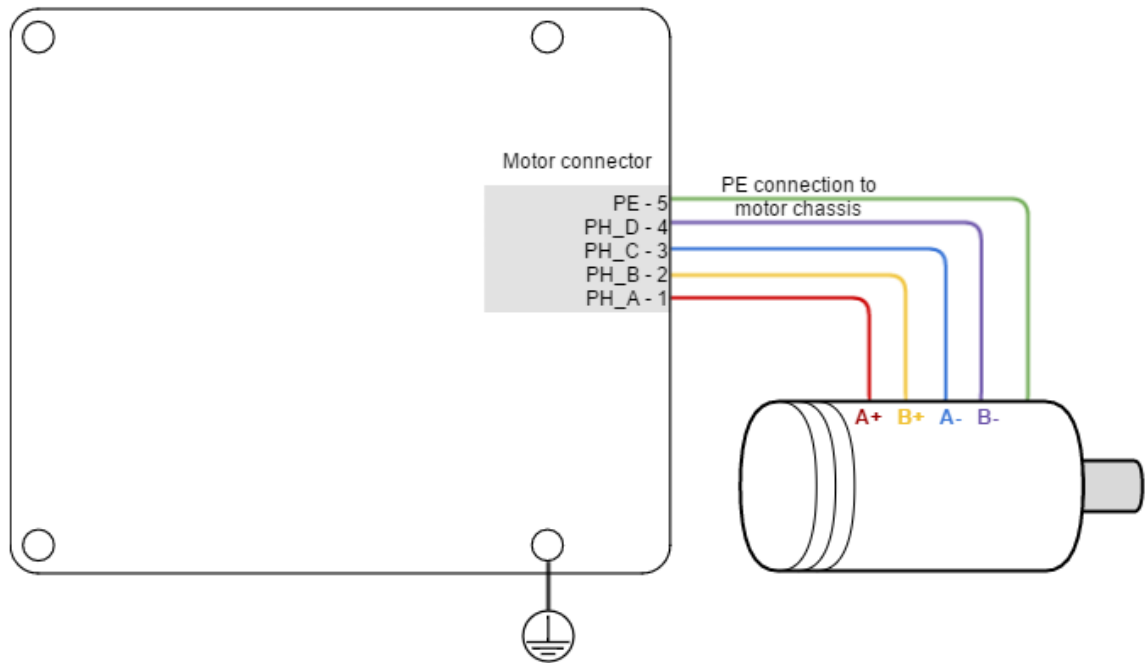
The protective earth (PE) connection is required for safety and should always be connected to a low impedance earth point. PE wire section should be, at least, the same as power supply cables.

Always minimize PE connection length. Having a central earth connection point is a good practice to avoid ground loops. Always use good quality plated screws that won't oxidize or lose conductivity during the expected lifetime. Whenever possible, mount the Hydra Servo Drive on a metallic conductive surface connected to earth. Note that the PE terminal is internally connected with the Hydra Servo Drive standoffs.

6.2 Motor output wiring

6.2.1 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.



6.2.2 External shunt 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.

① Configuration of the shunt

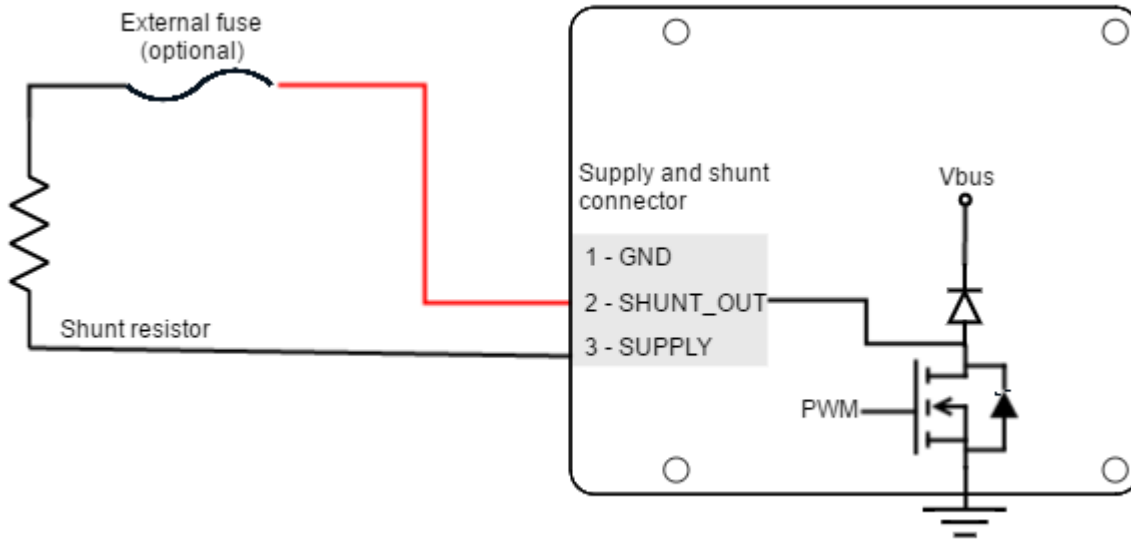
The shunt transistor can be configured using parameters in the register [0x2103 - Shunt configuration](#).

To set the shunt activation voltage use the registers in [0x2101 - Drive bus voltage](#). Set above the maximum expected DC supply voltage + 5%. When using batteries set the voltage > maximum charge voltage, this will allow regenerative braking and protect the battery against overcharging.

The external shunt resistor should be connected between SHUNT_OUT and SUPPLY pins of the Hydra [Supply and shunt connector](#).

It's strongly recommended to use an external fuse to limit the maximum power dissipation according to the chosen shunt resistor.

Shunt resistor connections should also be as short as possible to reduce parasitic inductances.



! Shunt resistor may have hot surfaces during operation.

Shunt resistor overview and sizing

While decelerating a mechanical load (abrupt motion brakes or reversals), the mechanical energy is converted into electrical energy by the motor. This energy is injected into the power supply and could lead to an increase of the supply voltage (depending on the power supply characteristics, especially its output capacitance) and then damage both the controller and the power supply.

A shunt circuit prevents the bus voltage from rising too high and therefore protects the Drive and the power supply. It is based on a resistor (sometimes referred as braking resistor) that is connected between the DC bus and GND through a power transistor.

This shunt transistor is automatically activated when the DC bus voltage exceeds a certain value defined by the user. Its PWM duty cycle can also be configured by the user.

In general, a battery powered system is capable of absorbing regenerative energy and therefore no shunt resistor would be needed. However only use this option if the battery is designed to accept negative current peaks and does not provide a reverse current protection. This information must be provided by the battery manufacturer. Reverse currents might cause catastrophic battery failure.

Shunt Resistor Sizing

To size the shunt resistor, the parameters in next table should be known or estimated.

Abbreviation	Parameter	Typical Value
Electrical parameters		
V_{NOM}	Nominal Bus voltage [V]	12 V to 48 V
V_{MAX}	Turn on voltage for shunt circuit, user configured maximum Bus voltage [V]	-
V_{HYS}	Hysteresis point of Bus voltage during deceleration cycles [V]	-
C	Bus capacitance [F]	>112 μ F (Hydra Internal)

Abbreviation	Parameter	Typical Value
DC	User configured shunt PWM Duty Cycle	0.5
I_{PH}	Phase current during deceleration [A_{RMS}]	-
R_{PH}	Motor phase resistance line to line [Ω]	-
Mechanical parameters		
ω_M	Motor angular velocity before deceleration [rad/s = rpm · 0.1047]	-
J_M	Motor moment of inertia [$kg \cdot m^2 = N \cdot m \cdot s^2$]	-
J_L	Load moment of inertia [$kg \cdot m^2 = N \cdot m \cdot s^2$]	-
T_F	Friction torque [$N \cdot m$]	-
t_D	Time to deceleration [s]	-
t_{CYC}	Time between decelerations cycles + t_D [s]	-
Calculated parameters		
E_K	System kinetic energy before deceleration [J]	-
E_L	Energy related to system loses during deceleration [J]	-
E_D	Net deceleration energy [J]	-
$P_{D(PK)}$	Deceleration peak power [W]	-
$P_{D(AV)}$	Average deceleration power on a cyclic system [W]	-
R_{SH}	Calculated shunt resistor [Ω]	5 to 200
P_R	Shunt resistor rated power [W]	-

Use following equations to calculate the net deceleration energy (E_D) (eqn. 1) by subtracting system loses during deceleration (E_L) (eqn. 2) from the kinetic energy (E_K) (eqn. 3) of the system before deceleration. If some parameters regarding system loses are not known, some terms may be cancelled in the formula, this may oversize the shunt resistor but is a safe approach.

$$(1) \quad E_K = \frac{1}{2} \cdot \omega_M^2 \cdot (J_M + J_L)$$

$$(2) \quad E_L = 3 \cdot I_{PH}^2 \cdot \left(\frac{R_{PH}}{2}\right) \cdot t_D + \frac{1}{2} \cdot \omega_M \cdot T_F \cdot t_D$$

(3)	$E_D = E_K - E_L$	
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If the calculated net deceleration energy (E_D) exceeds the energy that bus capacitors can store a shunt resistor is required, see eqn.4. Note that the minimum capacitance is the Hydra internal (600 μ F); however typical power supplies have large output capacitances that are parallel to the bus capacitance. Since battery operated systems allow regenerative braking this equation is not valid in this case. The worst case is a diode protected system.

(4)	$E_D < \frac{1}{2} \cdot C \cdot (V_{MAX}^2 - V_{NOM}^2)$	
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If a shunt resistor is necessary, the deceleration peak power $P_{D(PK)}$ should be calculated using eqn. 5.

(5)	$P_{D(PK)} = \frac{E_D - \frac{1}{2} \cdot C \cdot (V_{MAX}^2 - V_{NOM}^2)}{t_D}$	
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In systems with cyclic decelerations, the average deceleration power $P_{D(AV)}$ should be determined using eqn. 6.

(6)	$P_{D(AV)} = \frac{E_D - \frac{1}{2} \cdot C \cdot (V_{MAX}^2 - V_{HYS}^2)}{t_{CYC}}$	
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The shunt resistor rated power (P_R) must be higher than $P_{D(AV)}$. Deceleration peak power $P_{D(PK)}$ must be lower than the shunt resistor peak power during the deceleration time (t_D). Typically, resistor manufacturers provide graphs of resistor power depending on peak duration.

The maximum resistance value depends on the peak deceleration power and PWM duty cycle (DC). The user may choose a combination of DC and R_{SH} . It is recommended to have a duty cycle close to 50% since it will allow maximum braking flexibility. In case of doubt between two shunt resistor values it is suggested to choose the lowest resistance value since the DC can be easily adjusted.

(7)	$R_{SH} < DC \cdot \frac{V_{MAX}^2}{P_{D(PK)}}$	
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6.2.3 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 5 mm (connector pitch). Following table indicates recommended section:

Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	0.5 mm ²	1.5 mm ²
Solid wire	0.5 mm ²	1.5 mm ²

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 condition may not be met. 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. Typically the necessary values are around 100 μ H.

Wire ferrules

It is recommended to use wire ferrules to prevent cable damage or wrong contacts. Ensure crimped ferrule diameter does not exceed 1.5 mm and the insulator is < 3.5 mm. Following are some suggested ferrules:

Manufacturer	Part number	Image	Description
WAGO	216-201		0.5 mm ² (22 AWG)
WAGO	216-224		1.5 mm ² (16 AWG)

Motor choke

In applications where electromagnetic compatibility is a concern or that must comply with the EMC standards, the use of an external common mode choke is necessary. Place the choke as close to the driver as possible. 2 turns to the choke are recommended for best performance. Make sure the chosen choke does not saturate at the maximum operating phase current. If this happens, the choke temperature would increase rapidly.

Next table shows a choke that fits the Hydra Servo Drive specifications.

Type	Manufacturer	Reference
Low frequency ferrite	Laird Technologies	LFB360230-300

i Why are motor chokes useful

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 work also, the EMI reduction would be much lower than passing all the phases through the same choke. The PE (motor chassis) conductor should NOT pass through the choke.

Doing more than 2 turns is not effective as capacitive coupling between wires would bypass the choke effect.

6.3 Feedback connections

The motor [feedbacks connector](#) has inputs for differential or single-ended digital incremental encoders. Hydra Servo Drive also provides a 5 V @ 200 mA output for feedbacks supply. This output is overload and short circuit protected.

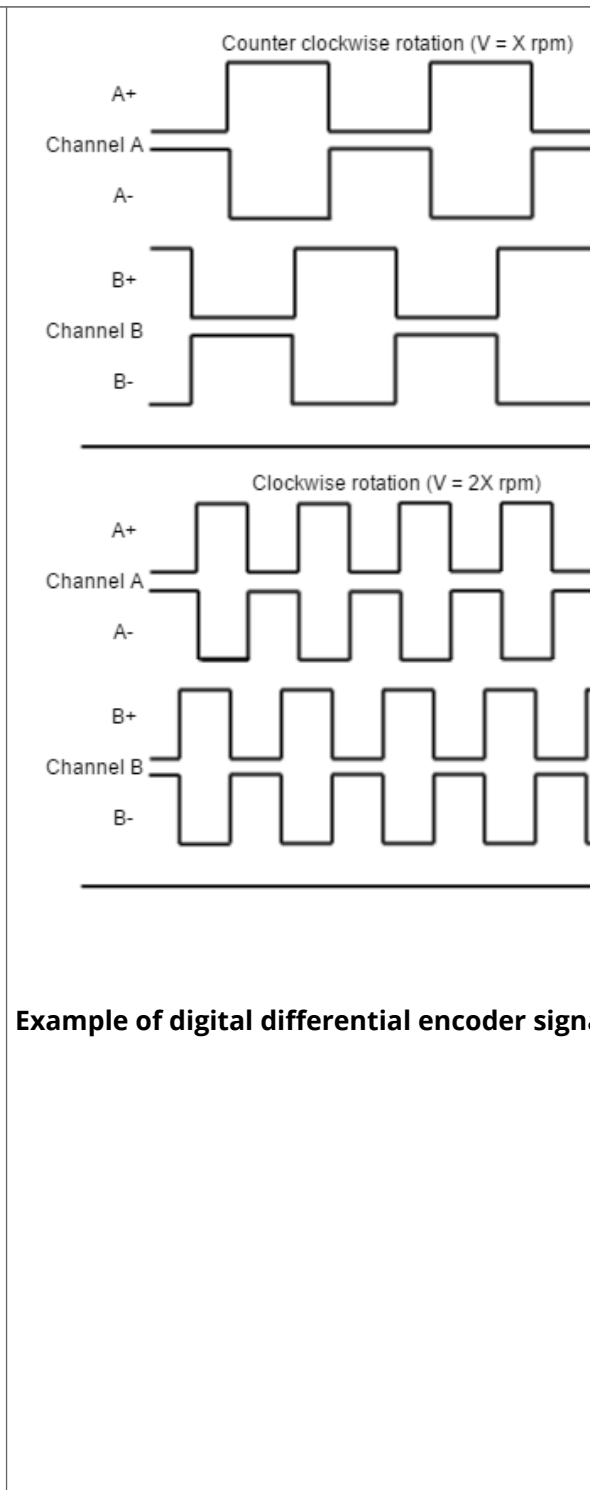
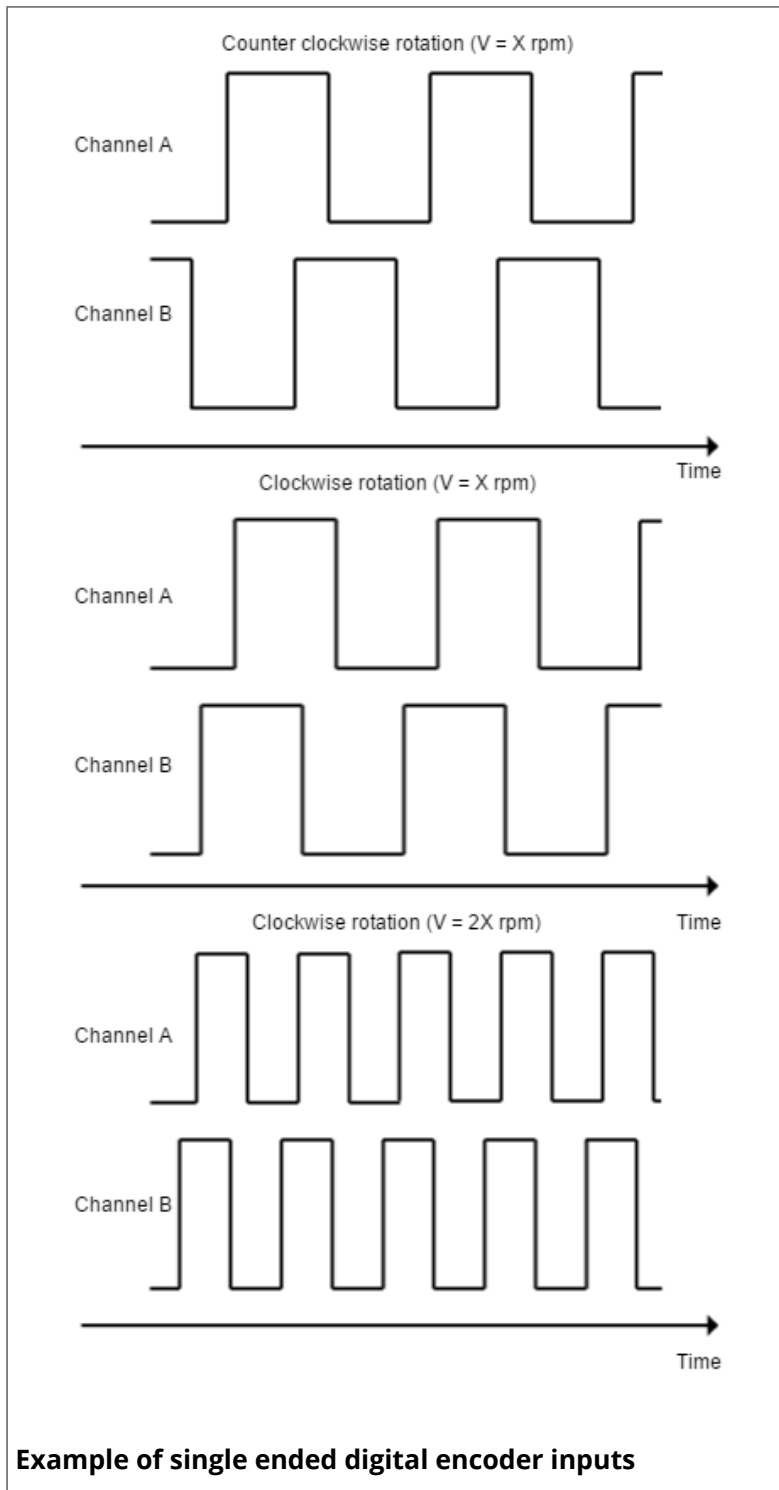
6.3.1 Digital encoder interface

Hydra Servo Drive can use single ended or differential encoder inputs for velocity and/or position control, with the option of using the encoder as a commutation sensor for the motor.

The encoder provides incremental position feedback that can be extrapolated into very precise velocity or position information. Using high resolution encoders allows Hydra Servo Drive to use sinusoidal commutation.

i The high resolution of motor mounted encoders allows excellent velocity and position control and smooth motion at all speeds. Encoder feedback should be used for applications requiring precise and accurate velocity and position control, and is especially useful in applications where low-speed smoothness is the objective.

The encoder signals are read as "pulses" that the Hydra Servo Drive uses to essentially keep track of the motor's speed, position and direction of rotation. Channel A and channel B signals are 50% duty PWM, with a phase shift of 90 degrees. Based on the speed and on the order in which these pulses are received from the encoder, the drive can deduce the motor velocity and physical location. For example, for clockwise rotation, the rising and falling edges of the channel B signal arrive before than those of the channel A. For counter clockwise rotation, channel B signal changes will arrive later than channel A ones. When velocity is increased, the frequency of the signal increases too. Next Figures show some examples of encoder signals at different speeds.



✔ The high resolution of motor mounted encoders allows excellent velocity and position control and smooth motion at all speeds. Encoder feedback should be used for applications requiring precise and accurate velocity and position control, and is especially useful in applications where low-speed smoothness is the objective.

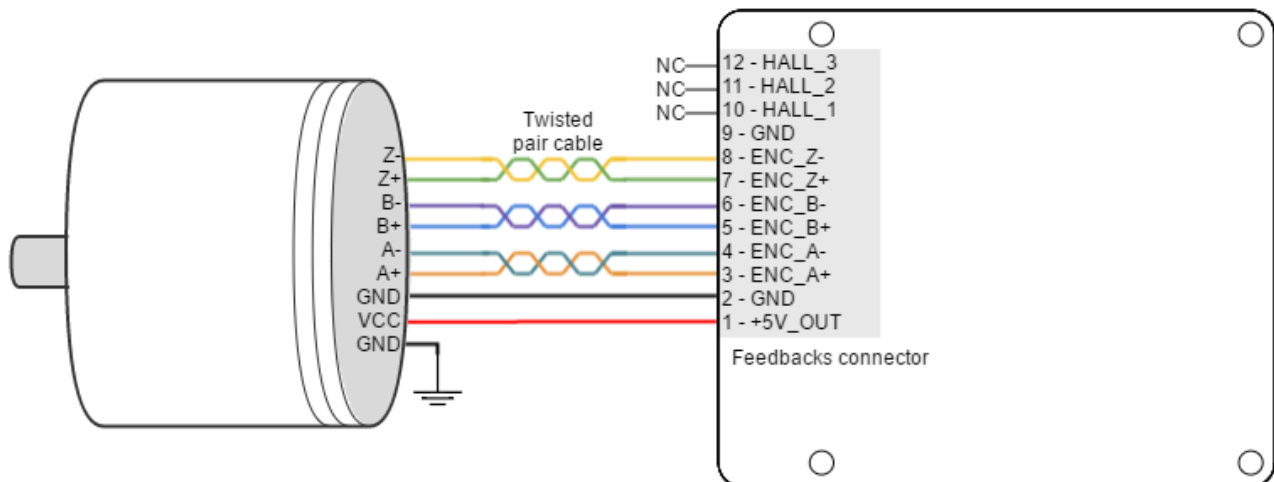
The Hydra Servo Drive has one differential quadrature encoder interface, with optional index signal input. Index is a single pulse per revolution signal that can be used to know absolute positions. Next Table illustrates digital encoder inputs main features.

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
Max working frequency	10 MHz
Termination resistor	120 Ω (between ENC_x+ and ENC_x-)
Bias resistors	ENC_x+ (positive input) 1 k Ω to 5 V ENC_x- (negative input) 1 k Ω to 2.5 V (equivalent)

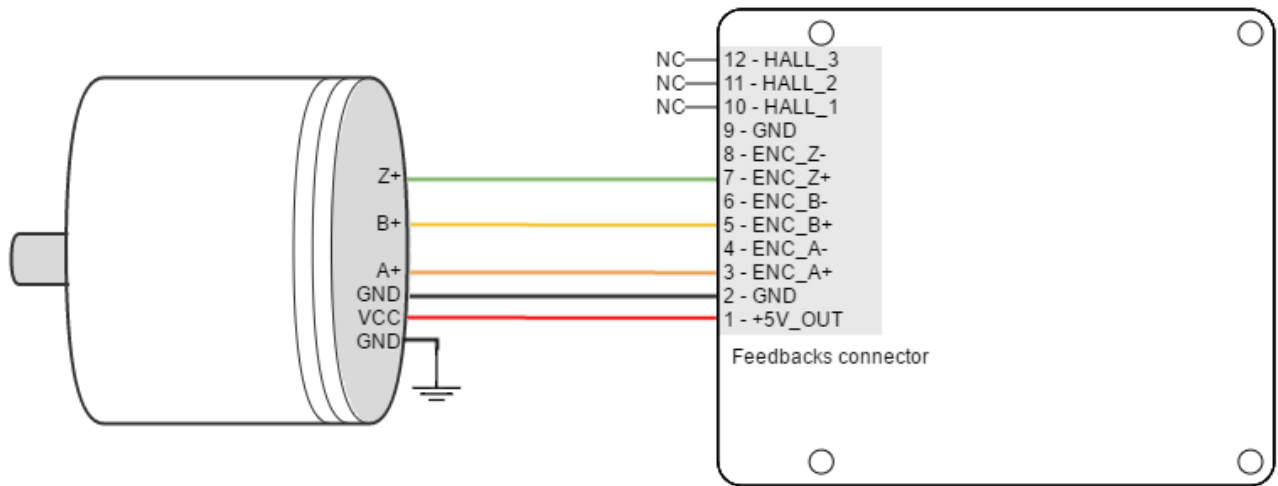
For encoder signal reception, an analog differential line receiver with an hysteresis comparator is used. The high signals (ENC_A+, ENC_B+ and ENC_Z+) are pulled up to +5 V, and the low signals (ENC_A-, ENC_B- and ENC_Z-) are biased to 2.5 V. This arrangement let user to connect either open collector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

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

Next 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.

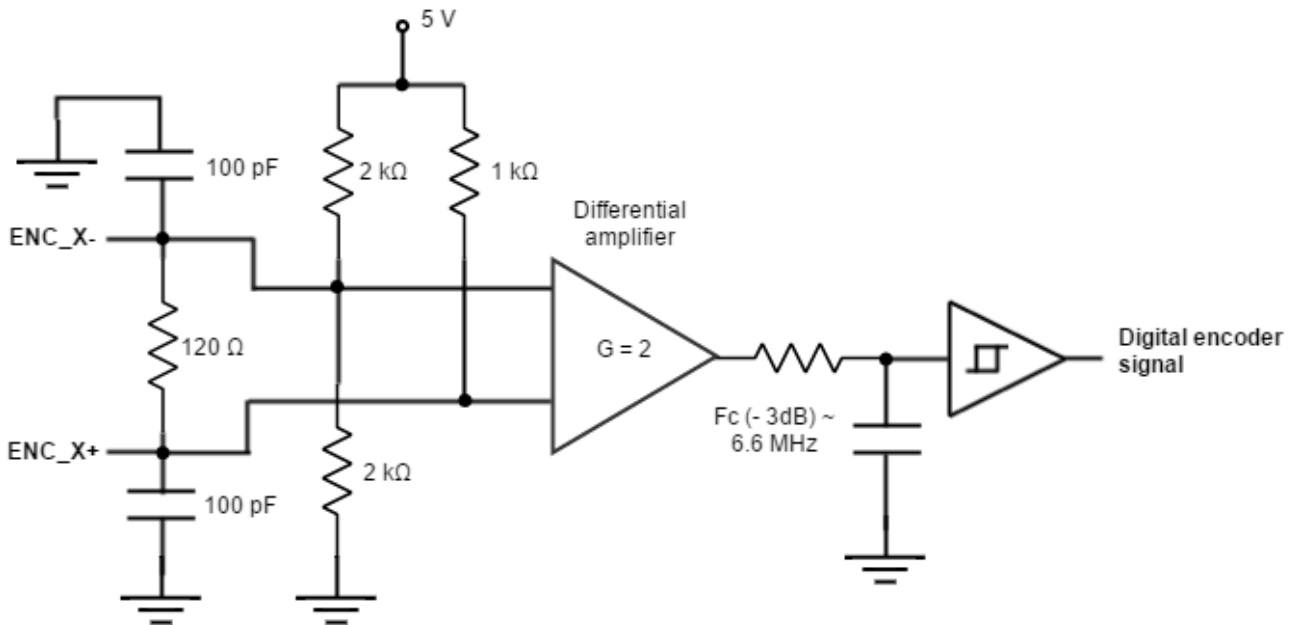


Connection diagram for digital differential encoders.



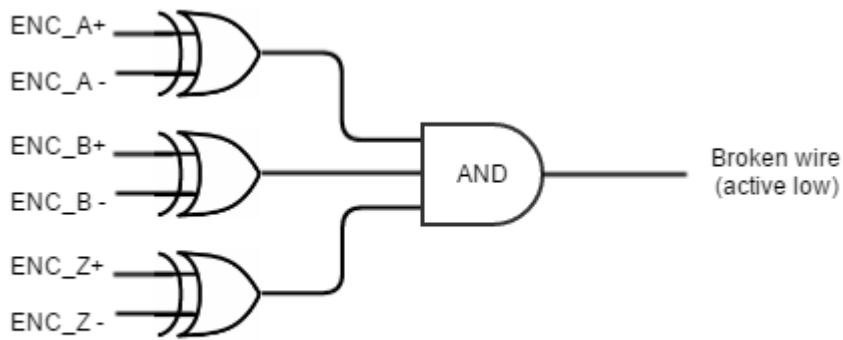
Connection diagram for digital single ended encoders.

Next Figure shows the circuit model of the digital encoder inputs:



Encoder broken wire detection

For differential digital encoders only a broken wire detection circuit is included. The circuit is based on 3 EX-OR gates only works for differential encoders.



3 x XOR: The inputs must be differential. Positive and negative signals for any encoder signal must be different.

✔ The encoder broken wire detection only works when the encoder is **configured as differential**. An **error** will be generated if the encoder is disconnected or some wire is broken.

⚠ To avoid a broken wire fault if 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.

✔ If the encoder is properly connected and the broken wire activates, just configure the encoder as single ended. The robustness of the signal is the same and the system will work perfectly.

6.3.2 Feedback wiring recommendations

The most frequent problems encountered in transmitting feedback signals to the receiving electronics are signal distortion and electrical noise. Either problem can result in gain or loss of counts for digital feedbacks or bad voltage levels for analog ones. To minimize these problems there are some essential good wiring practices that should be followed:

1. Always connect both positive and negative signals when using differential digital encoders, Hall sensors, PWM encoders or analog feedbacks. Use one twisted pair for each differential group of signals and another twisted pair for the 5 V supply and GND.
2. Keep the ground connection between an encoder and the Hydra Servo Drive even if the encoder supply is not provided by the drive. In very noisy environments, connect the cable shield to the connector shield only at one side. Never use the shield as a conductor carrying a signal, for example as a ground line.
3. It is essential to keep feedback devices wiring as far as possible from motor, AC power and all other power wiring.

Analog signals specific wiring recommendations

Following are several recommendations for analog signals wiring which can effectively reduce noise interference:

1. Use **twisted pair cable** to improve noise immunity. 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.

2. Connect the common of the signal source to Hydra GND if available to minimize common mode noise.
3. Use an isolated power supply for the analog input circuit, this will prevent the formation of ground loops.
4. If the analogue signal source is single-ended and the signal source ground is isolated from the drive GND, use a 2-wire shielded cable as follows: 1st wire connects the live signal to the drive analog input 1; 2nd wire connects the signal ground to the drive ground.
5. If the analogue signal source is single-ended and the signal source ground is common with the drive GND, use a 2-wire shielded cable as follows: 1st wire connects the live signal to the drive analog input 1; 2nd wire connects the signal ground to the drive ground.
6. If the analogue signal source is differential and the signal source ground is isolated from the drive GND, use a 3-wire shielded cable as follows: 1st wire connects the signal plus to the drive analog 2 positive input (2+); 2nd wire connects the signal minus to the drive analog 2 negative input (2-) and 3rd wire connects the source ground to the drive GND.
7. If the analogue signal source is differential and the signal source ground is common with the drive GND, use a 2-wire shielded cable as follows: 1st wire connects the signal plus to the drive analog 2 positive input (2+); 2nd wire connects the signal minus to the drive analog 2 negative input (2-).
8. For all of the above cases, connect the cable shield to the signal source connector frame and leave the other shield end unconnected to avoid ground loops. To further increase the noise protection, use a double shielded cable with inner shield connected to signal source GND and outer shield connected to the signal source I/O connector frame. Leave both shields unconnected on the driver side.
9. If the signal source output voltage is larger than +/-10 V, use a 3-resistor differential divider, located near the servo drive connector.

6.4 IO connections

The Hydra Servo Drive provides various [input and output pins](#) for parameter observation and drive configuration options.

The input and output pins are summarized below:

- 2 x 5 V non-isolated digital outputs.
- 2 x 5 V low speed non-isolated single ended digital inputs. (GDI1, GDI2)
- 2 x 5 V high speed non-isolated differential digital inputs.
- 1 x (± 10 V) differential 12 bits analog input.
- 1 x 0 – 5 V differential 12 bits analog input.

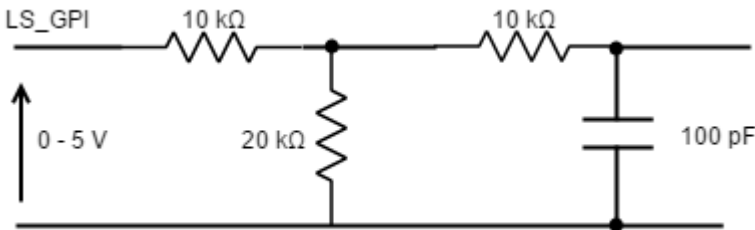
6.4.1 Low-speed (LS) single ended digital inputs interface

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

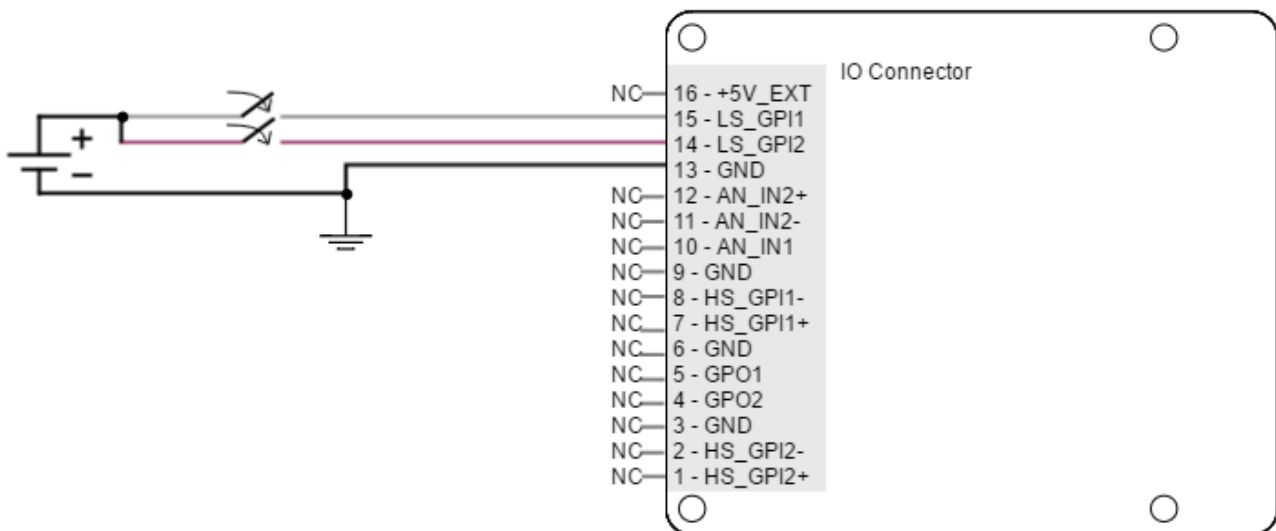
Specification	Value
Number of inputs	2 (GPI1, GPI2)
Type of input	Single ended. ESD protected. Low pass filtered.
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Input current	0.7 mA @ 5 V; 2 mA @15 V
High level input voltage	$4.5 \text{ V} < V_{in} < 24 \text{ V}$

Specification	Value
Low level input voltage	$0 < V_{in} < 1 \text{ V}$
Input impedance	30 kΩ
Max delay	2 μs
Max frequency	~ 200 kHz

Inputs electrical equivalent circuit is the following:

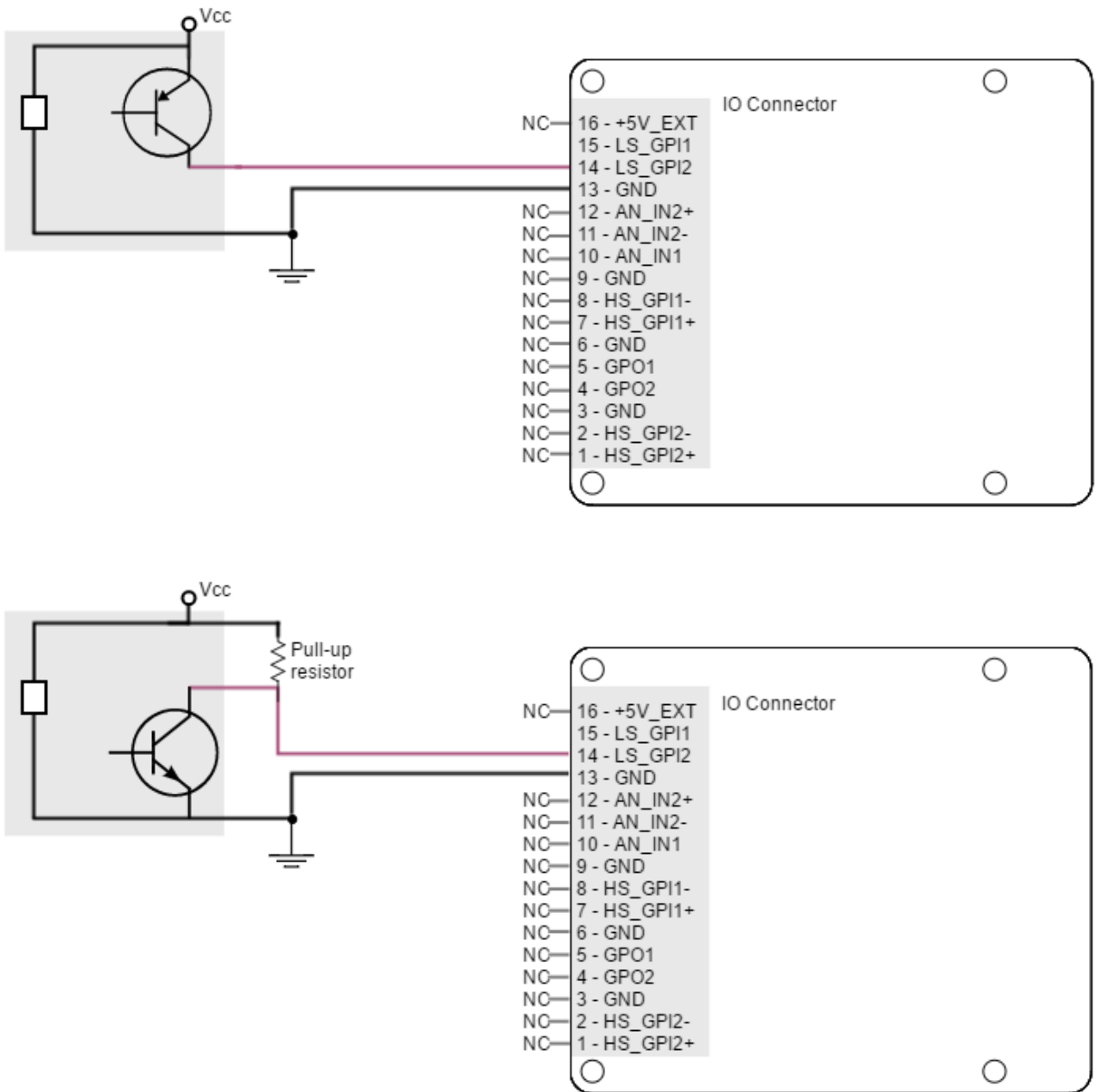


Next figure shows proper inputs connection:



! 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.

Three-wire sensors can also be connected to Hydra Servo Drive LS inputs. Next figures illustrate how to do it for PNP and NPN 3 wire sensors (LS_GPI1 can also be used).



Pull up resistor value must be chosen in order to ensure ≥ 4 V at the GPI pin considering the input 30 k Ω resistance. For Vcc 5 V, 1 k Ω is recommended. For 24 V 10 k Ω .

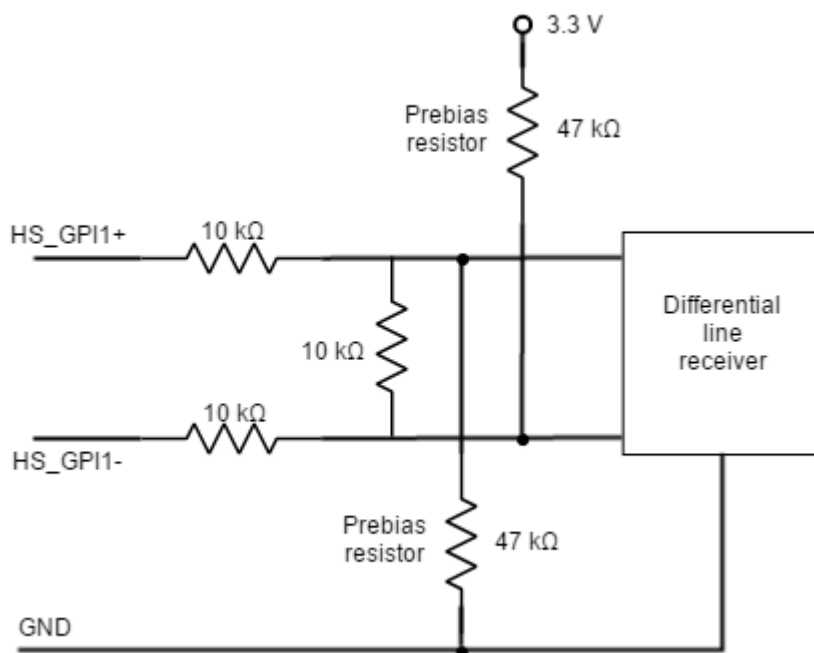
6.4.2 High-speed (HS) digital inputs interface

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

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

Specification	Value for 5 V inputs
High level input voltage	$(HS_GPI+ - HS_GPI-) > 150 \text{ mV}$
Low level input voltage	$(HS_GPI+ - HS_GPI-) < -600 \text{ mV}$
Maximum working input voltage	$\pm 24 \text{ V}$
Total rising delay	65 ns
Total falling delay	55 ns
Receiver differential threshold voltage	$-7 \text{ V} \leq V_{CM} \leq 12 \text{ V}$ (V_{CM} common mode input voltage)
Receiver input hysteresis	25 mV ($V_+ + V_- = 0$)
Max frequency	10 MHz

Next figures show the circuit model for High speed digital input. Resistance values are 10 k Ω which results on a 30 k Ω line impedance. If lower impedance is desired, a termination resistor can be placed between HS_GPI+ and HS_GPI-.

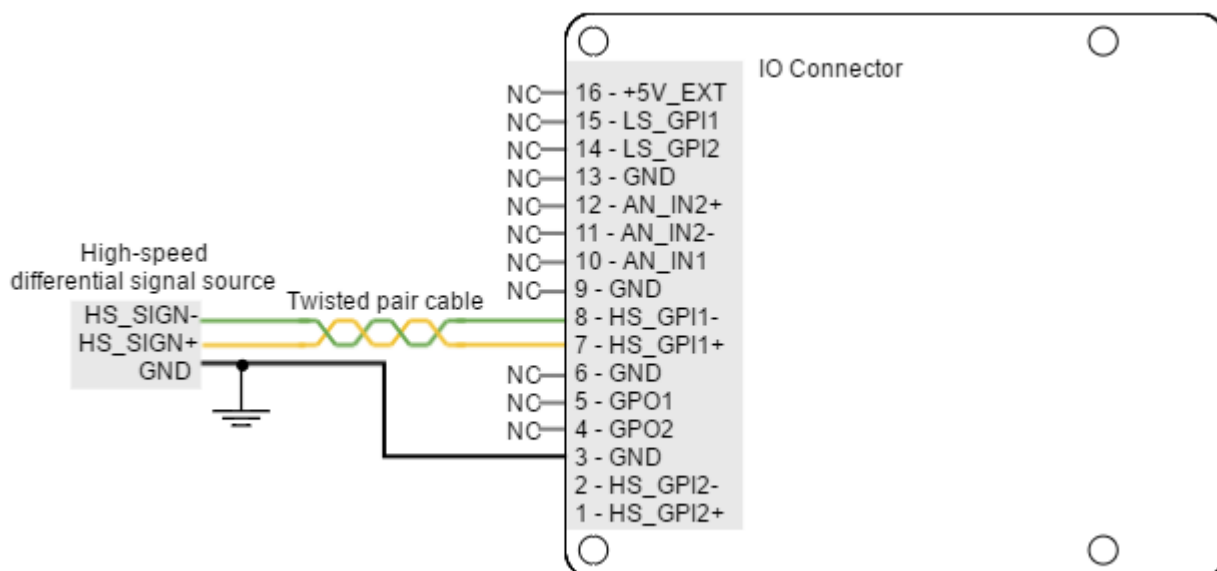


For these inputs work as single ended, tie HS_GPIx- to GND, and connect the input signal to the positive HS_GPI+ input.

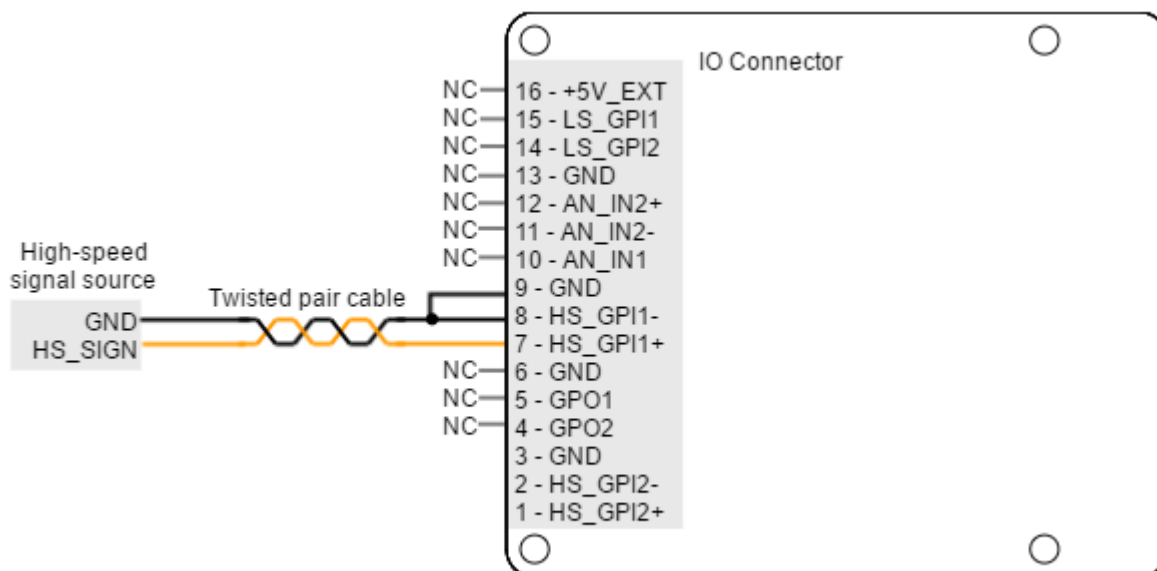
i HS_GPI1+ and HS_GPI2+ inputs are in LOW state by defect.

! 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.

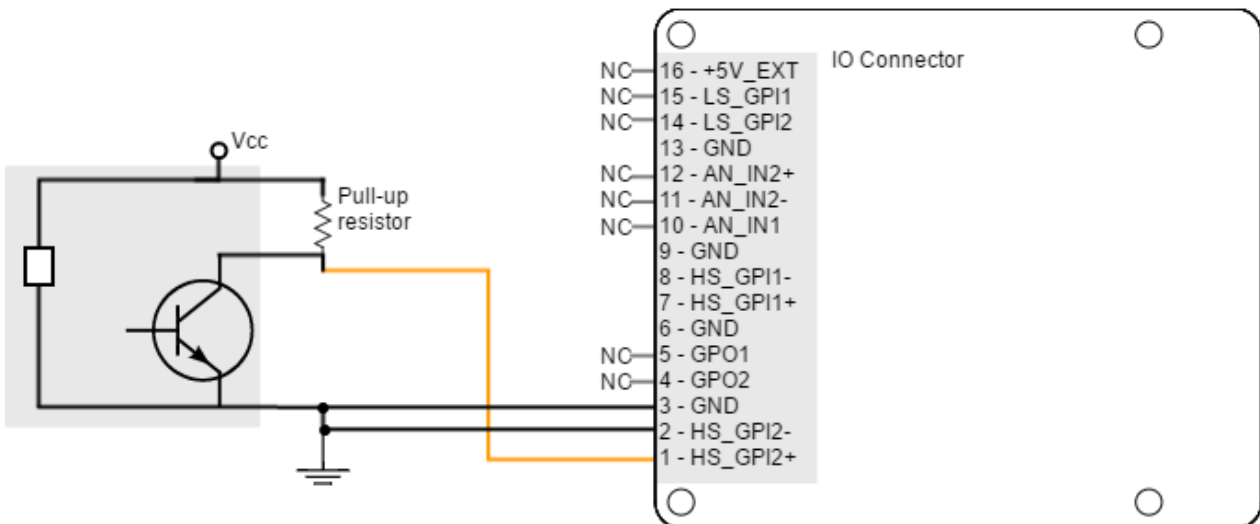
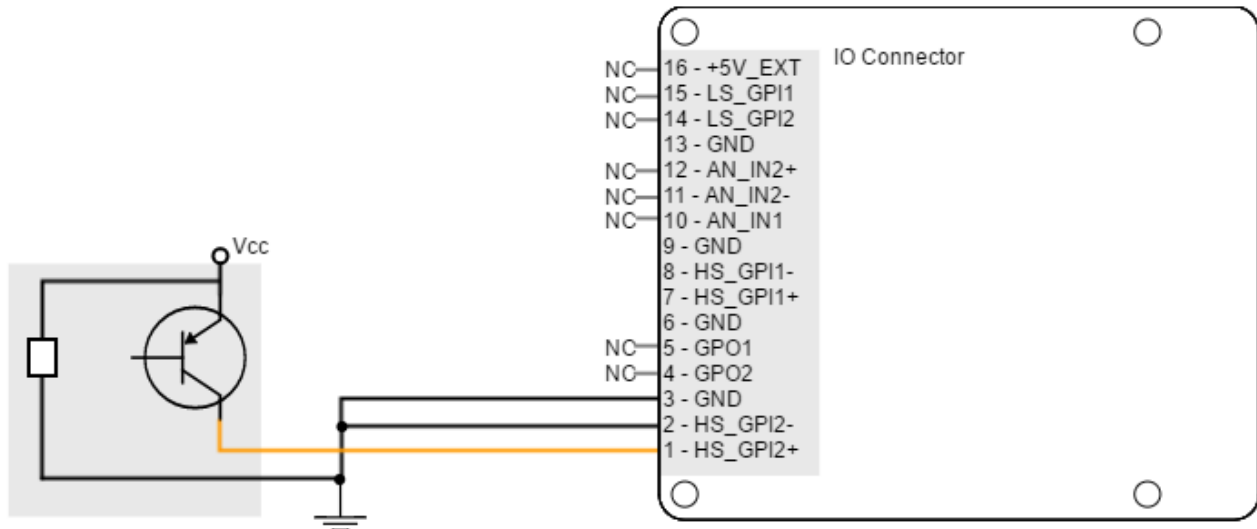
Next figure shows an example on how to connect differential sources to these inputs:



If a single ended input is used follow the next recommendation:



For three wire sensor connection to these inputs, refer to next figures:



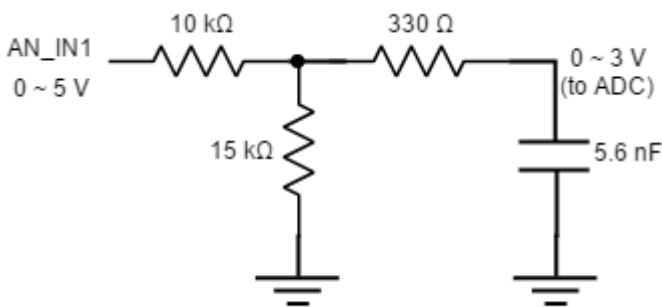
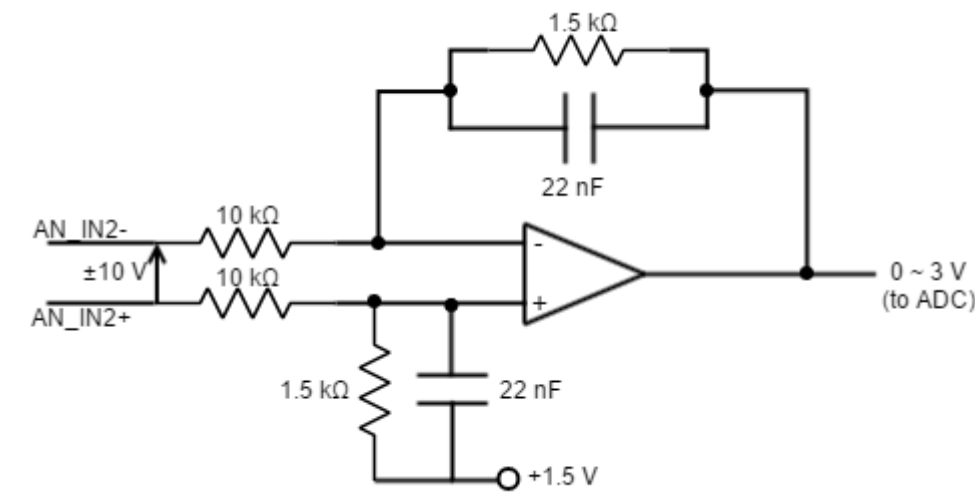
6.4.3 Analog inputs interface

Hydra Servo Drive has two 12-bit analog inputs with different input voltage ranges. Next Table shows their main features:

Specification	Value
Number of inputs	2
Type of inputs	Differential (input 2) Single ended (input 1) ESD protected.
ESD capability (input 2)	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
ESD capability (input 1)	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Analog input resolution	12 bits

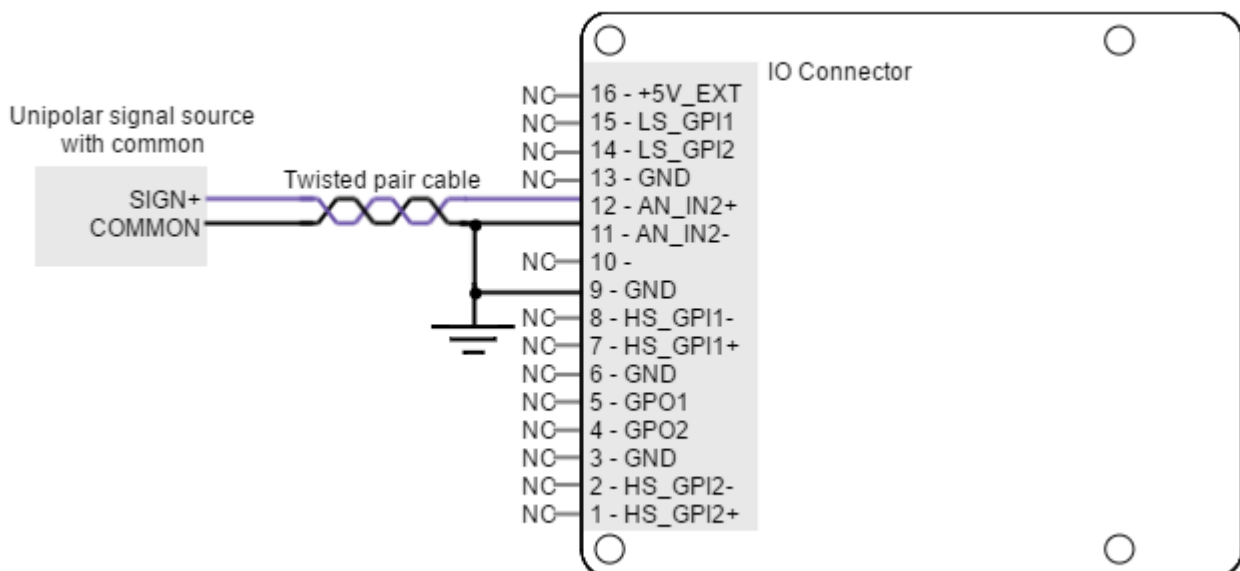
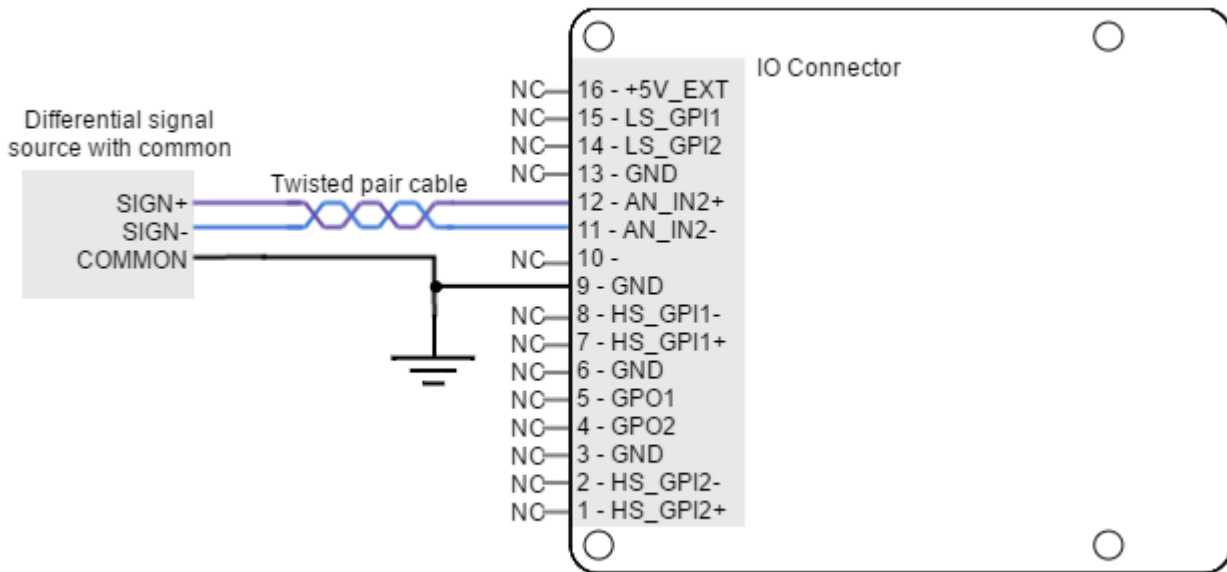
Input 2 differential voltage range	$\pm 10\text{ V}$
Input 2 max common mode range	$-10 \sim +10\text{ V}$
Input 1 voltage range	$0 \sim +5\text{ V}$
Maximum working frequency	10 kHz
Maximum voltage on any input pin for analog inputs (referred to GND)	+24 V
Input impedance	see schematic

Next figures illustrate analog inputs circuit models:

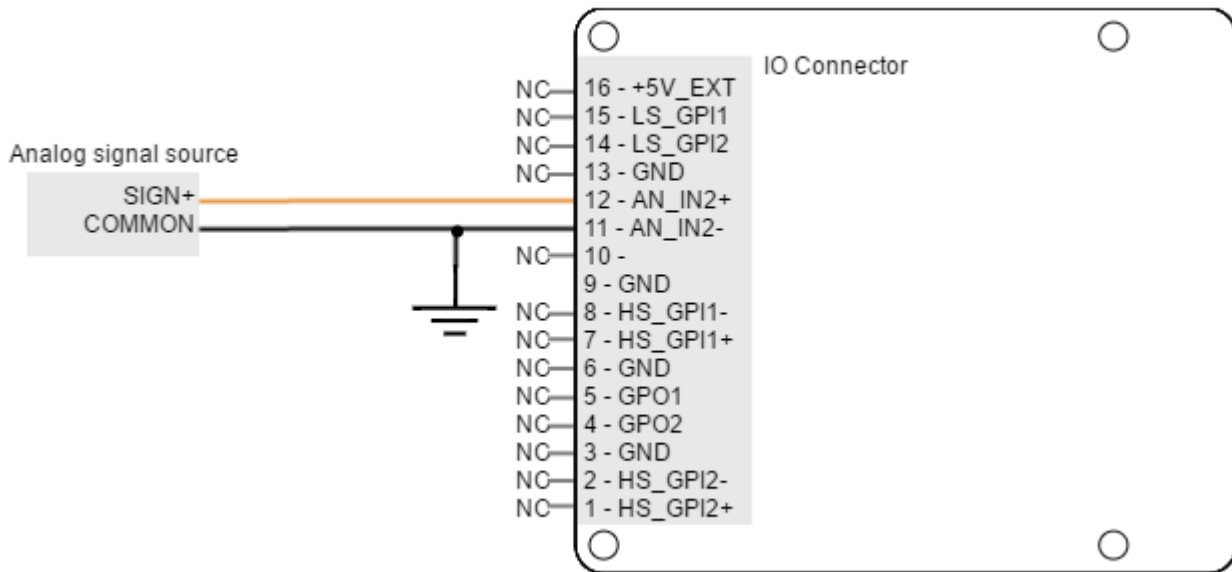


✔ To get a 0 ~ 10 V input range in AN_IN1 input, place a 70 kΩ resistor in series with the input.

Next figure shows how to interface voltage sources to the differential analog input 2. The differential analog input is typically used as a command source. Refer to [Feedback wiring recommendations](#) for more information about connections and wires.



To interface to a single ended (non-differential) voltage source, use analog input 1:

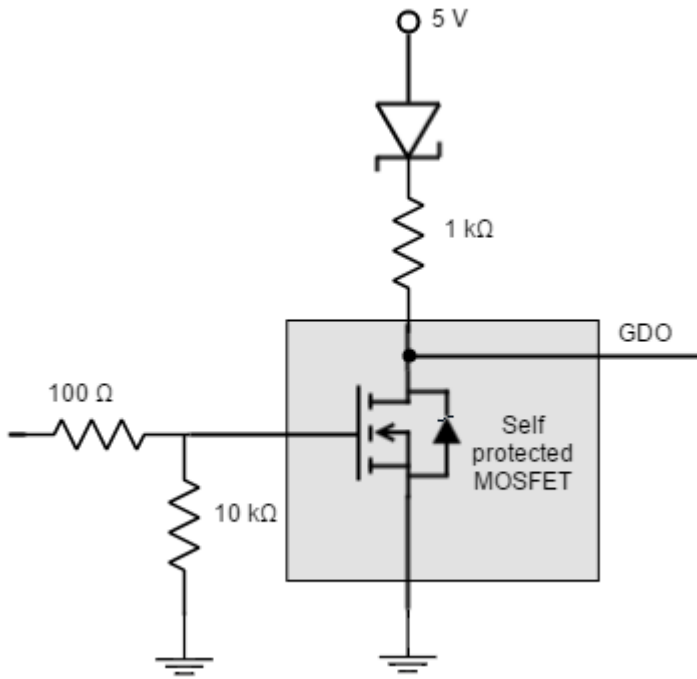


6.4.4 Digital outputs interface

Hydra Servo Drive has two digital non-isolated outputs. Refer to [IO Connector](#) for connectors position and pinout. Next table shows their main features:

Specification	Value
Number of outputs	2
Type of output	ESD protected. Overload, short circuit and overtemperature 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 $R_{load} = 100\text{ k}\Omega$ 20 μs @ 5 V and $R_{load} = 100\text{ k}\Omega$
OFF_ON delay	15μs @ 30 V and $R_{load} = 100\text{ k}\Omega$ 50 μs @ 5 V and $R_{load} = 100\text{ k}\Omega$
Max working frequency	3.5 kHz

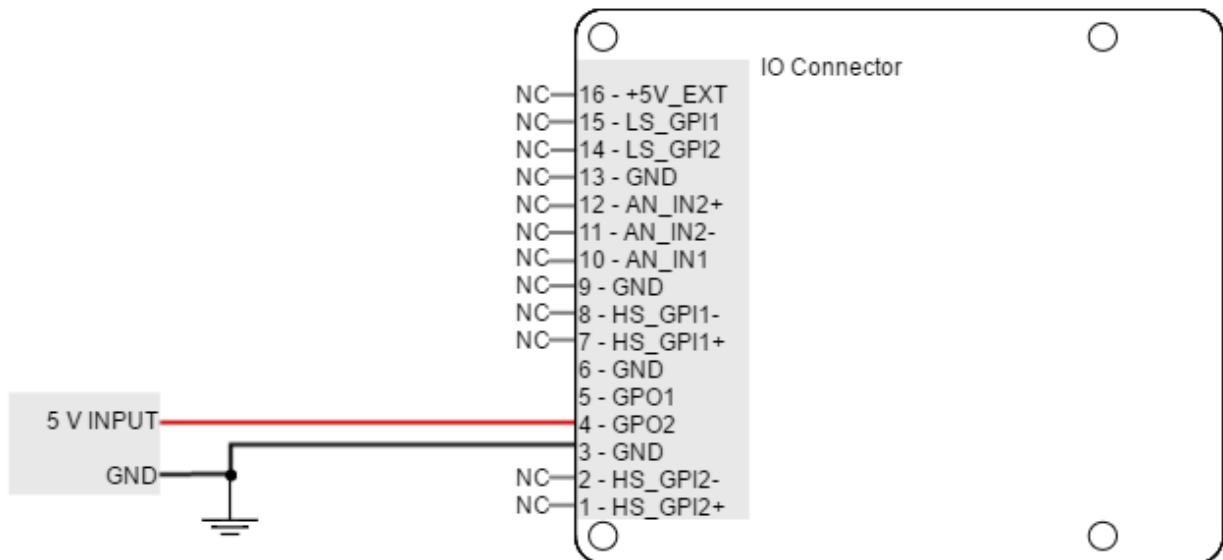
Next figure shows digital outputs circuit model.



Load should be connected in a different way depending on desired voltage levels.

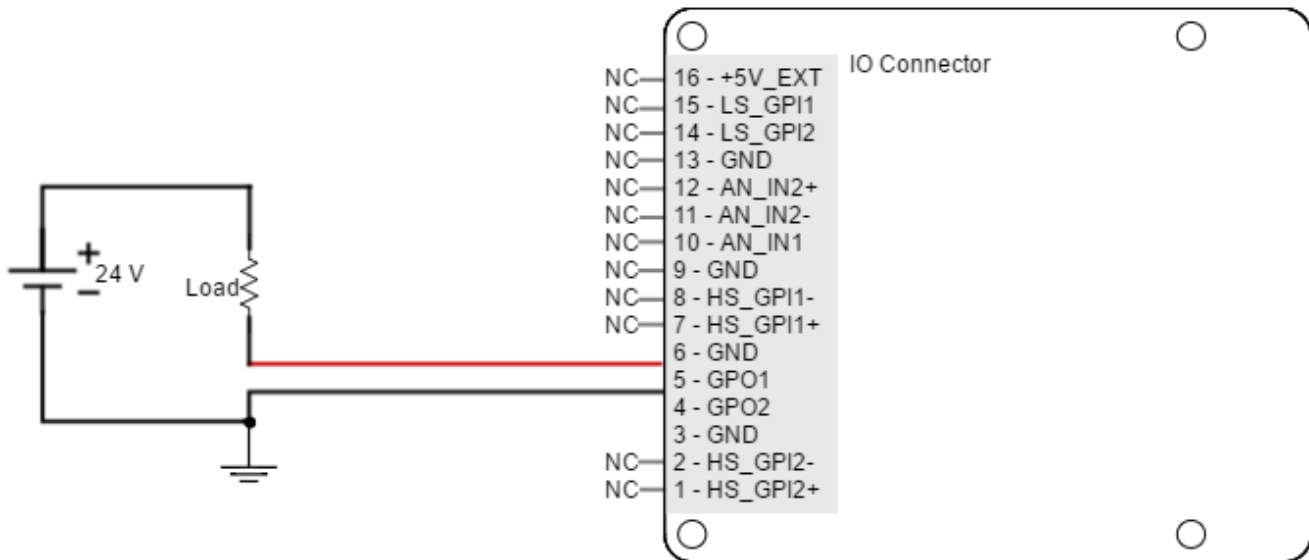
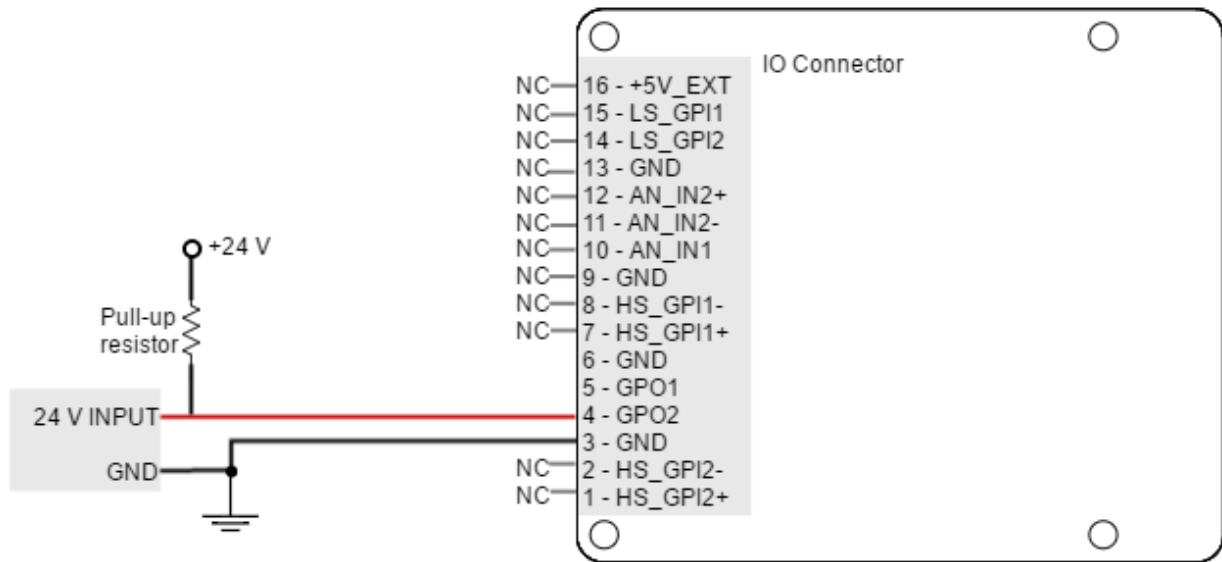
5 V outputs

Next figure illustrates how to connect a load to 5 V digital outputs (GPO1 can also be used).



24 V outputs

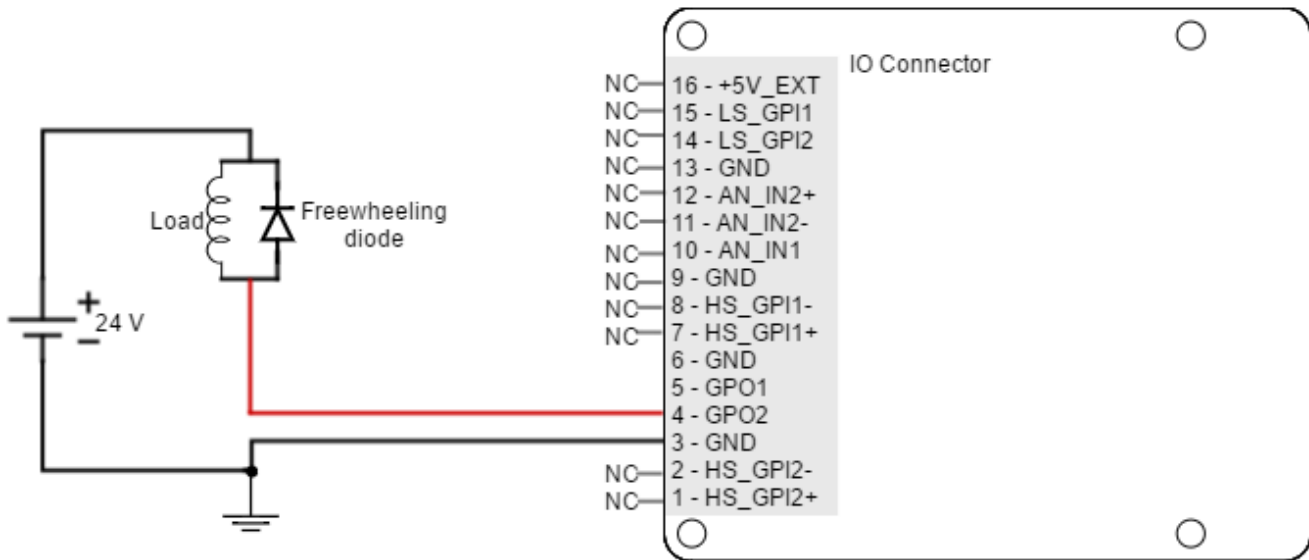
If 24 V outputs are needed, an external power supply should be used. For this option, outputs may be connected as voltage or current outputs. Next figures illustrate how to do it (GPO1 can also be used).



For inductive loads, it is recommended to place a diode (known as freewheeling diode) anti-parallel with the brake (i.e., Anode connected to the negative pole of the brake and cathode connected to the positive pole). These will prevent inductive kicking (voltage rise when current through the inductor falls to zero).

i Standard rectifier diodes such as [1N4002](#) or [1N4934](#) are appropriate for the application.

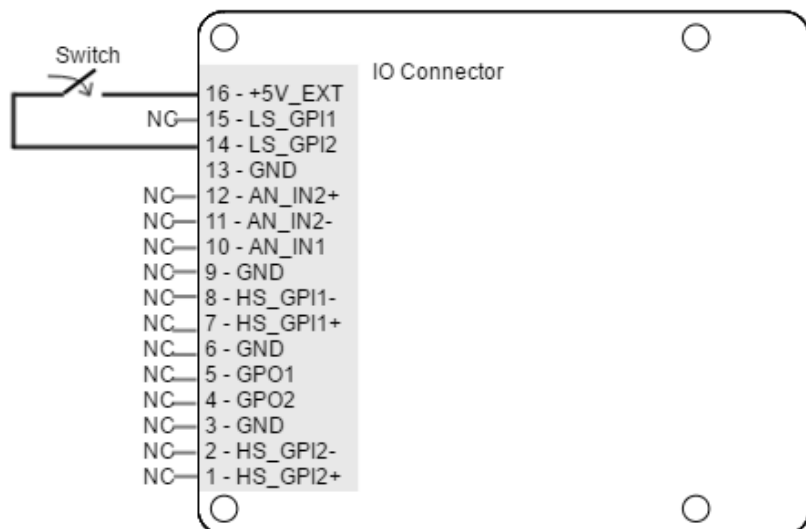
Actually, there are other options to avoid inductive kicking. Instead of a diode, a varistor or a RC snubber in parallel with the brake can also be used. This will improve transistor turn off time. Next figure show how to connect an inductive load to Hydra outputs (GPO1 can also be used).

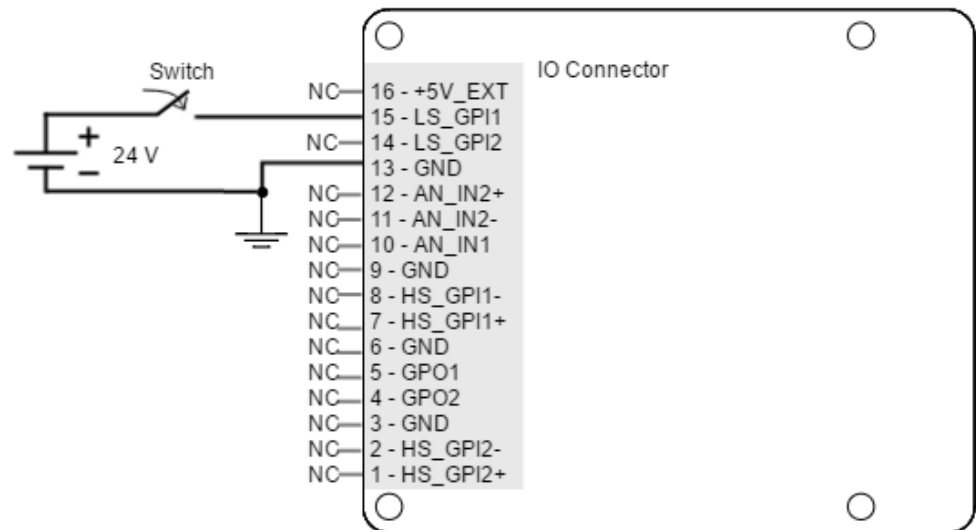


! Hydra Inputs and outputs are not isolated. The ground of the Hydra and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

6.4.5 Torque off input

As assembly option (custom), the Hydra Servo Drive has a torque off input used to prevent motor torque in an emergency event while the Hydra remains connected to the power supply. The **LS_GPI2** is used for this purpose. When the torque off input is activated, the power stage is disabled automatically, and the motor shaft will slow down until it stops under its own inertia and frictional forces. The power stage will remain activated while the LS_GPI2 has a logic high state ($4\text{ V} < V_{in} < 24\text{ V}$), and will be disabled with a logic low state ($0\text{ V} < V_{in} < 1\text{ V}$). The LS_GPI2 input has a logic low state by defect, so the switch must be connected to a logic high level to activate the power stage. Next figures show an example to connect the torque off input in two different ways. The self supplied option and the external supplied option:





⚠ 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.

6.5 Command sources

The command source input for the Hydra Servo Drive can be provided by one of the following options:

1. Network interface (CANopen, RS485 or USB).
2. Stand alone.
3. Analog input ($\pm 10\text{ V}$ or $0 \dots 5\text{ V}$).
4. Step and direction.
5. PWM command (single and dual input mode).
6. Encoder following / electronic gearing.

For command sources 3, 4, 5 and 6 general purpose inputs are used. Next Table illustrates command source options and which parameters can be controlled.

Please see [Command sources \(old\)](#) page for further details on configuration parameters.

Command source	Controlled parameter
Network interface	Position, velocity, torque
Standalone	Position, velocity, torque
Step and direction	Position
Encoder following / electronic gearing	Position
Analog input ($\pm 10\text{ V}$ or $0 - 5\text{ V}$)	Position, velocity, torque
PWM command	Position, velocity, torque

6.5.1 Network 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 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 the CAN interface or the RS-485 interface. These interfaces are more robust against noise than USB, and allow higher distances between the Hydra Servo Drive and the commander. Using these command sources, target position, velocity or torque can be set.

6.5.2 Standalone

Hydra Servo Drive is provided with an internal non-volatile memory. Through the appropriate software tool, user can 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 an external command source.

The user can program macros configuring target position, velocity or torque. Interface with general purpose inputs and outputs can also be programmed in the macros.

This feature can be very useful in applications such as production lines or test equipment, where repetitive movements are usual. Please refer to [Programming your Drive](#) for further information.

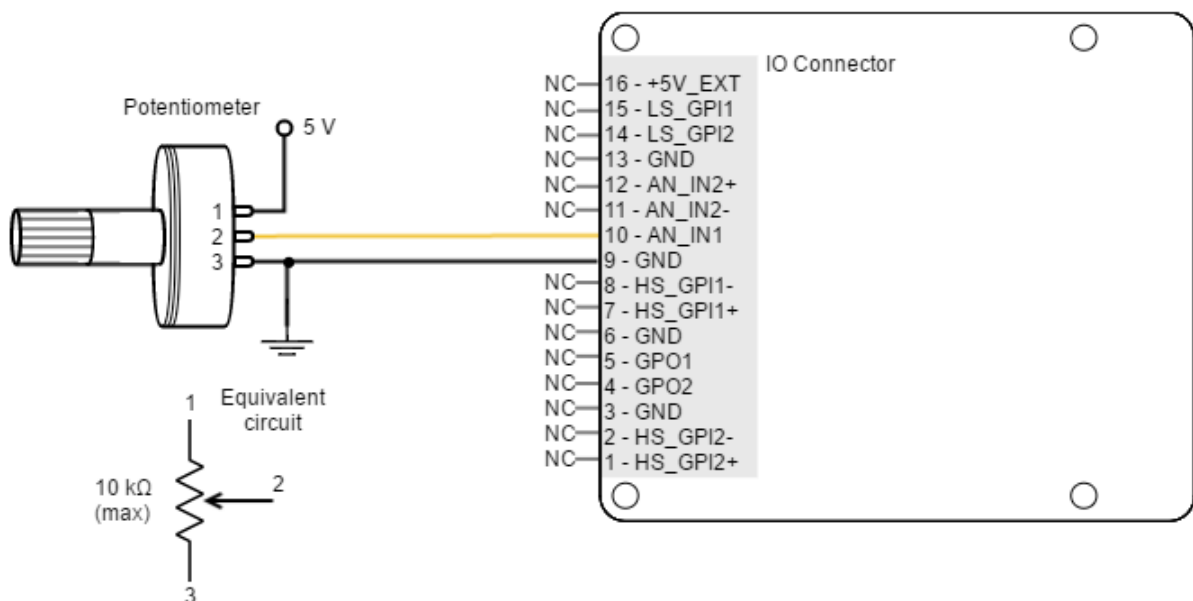
6.5.3 Analog input

User can control the target position, velocity or torque using an analog signal. Any of the general purpose analog inputs can be used as command source (depending on input voltage range and type of output of the commander).

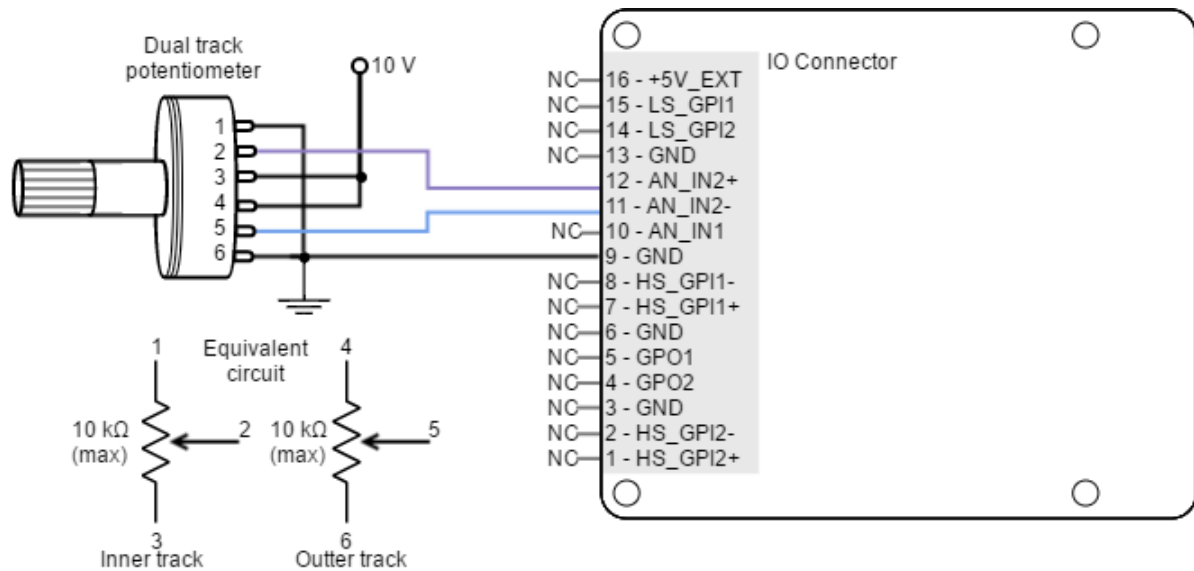
Hydra Servo Drive provides two analog inputs, one ± 10 V differential input and one 0 to 5 V single ended input. Refer to [Analog inputs interface](#) for more details about analog inputs.

The examples shown below are implemented in the [IO Starter Kit Documentation Home](#).

The next picture shows how to connect a potentiometer to get a 0 to 5 V input single ended.



As an application example, the next picture shows how to connect a dual track potentiometer to get a ± 10 V differential input.



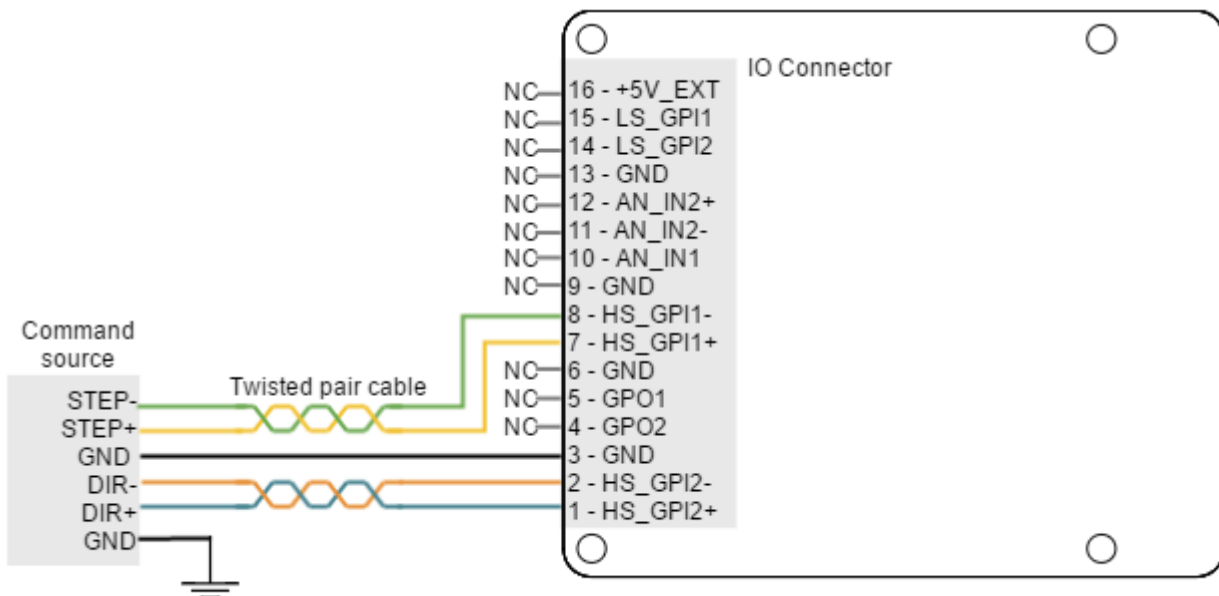
The most usual example of use for this command source is the use of joysticks (or other kinds of potentiometers) for controlling the position or velocity of a system.

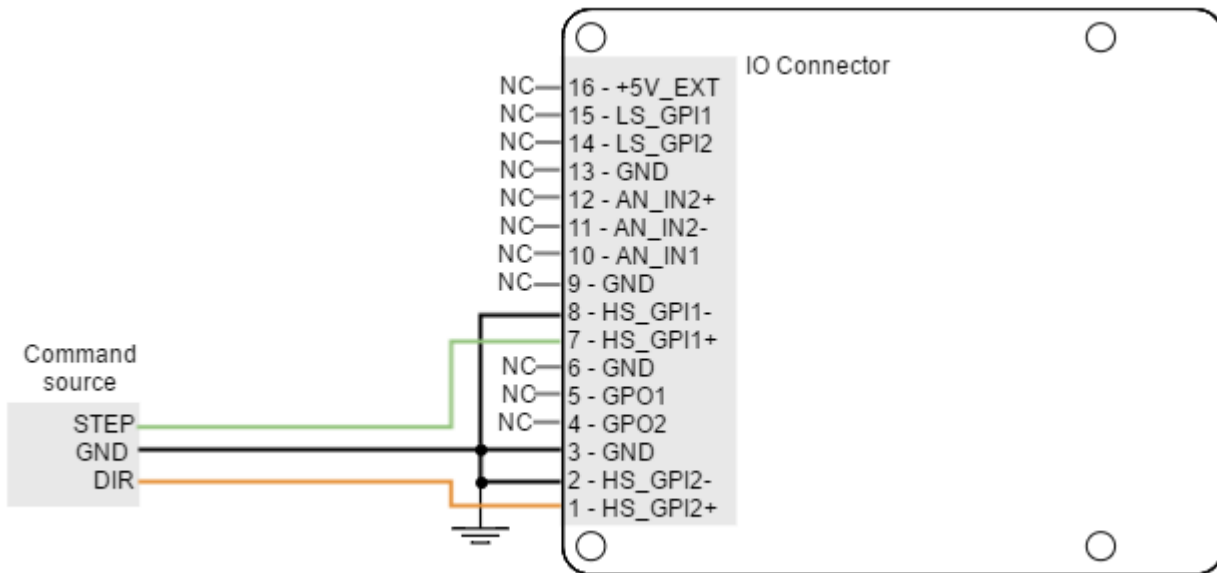
6.5.4 Step and direction (Pulse and direction)

For this command source, the driver typically accepts 2 inputs from an external source: Step (pulse) and Direction. The direction signal sets the direction of rotation (for example, "logic 0" for clockwise rotation and a "logic 1" for counter clockwise rotation). Pulse signal is a ~50% PWM 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.

General purpose high speed digital inputs are used here. HS_GPI1 is the Step input, and HS_GPI2 is the Direction input. Next figures illustrates how to connect a step and direction command source to the Hydra Servo Drive (for differential and single ended mode).

Refer to [Connectors](#) for information about connector position and pinout, and see [High-speed \(HS\) digital inputs interface](#) for more information about digital inputs. Next figure shows how to connect this input:





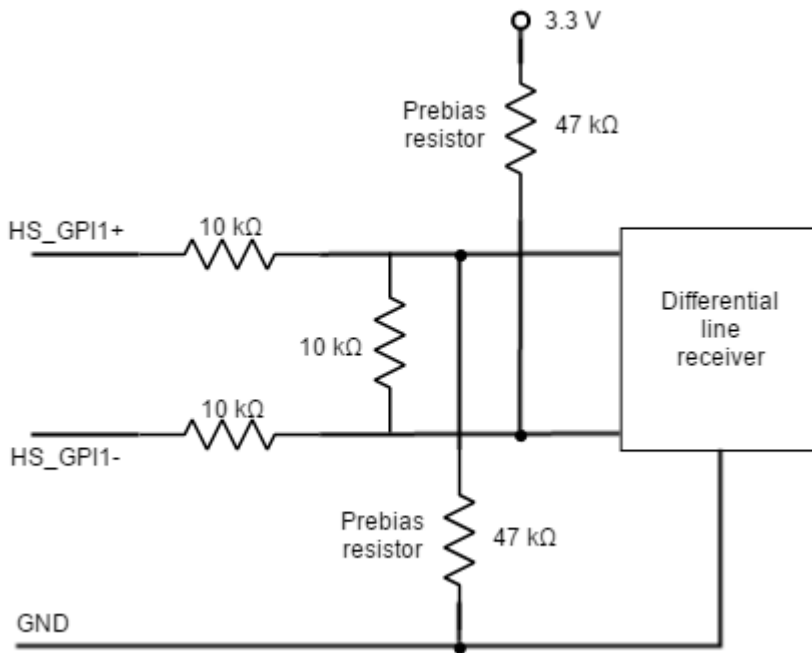
6.5.5 PWM command

PWM input signal specification

For this feedback interface the High Speed digital input 2 is used (HS_GPI2). Next table summarizes main features of this input:

Specification	Value
Number of inputs	1
Type of input	ESD protected. Differential using RS422 receiver.
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Input current	2 mA @ 5 V; 5 mA @ 15V
High level differential input voltage	$(HS_GPI2+ - HS_GPI2-) > 150$ mV
Low level differential input voltage	$(HS_GPI2+ - HS_GPI2-) < -600$ mV
Recommended PWM signal for single ended	$1.2 V_{pk}$ to $24 V_{pk}$ (HS_GPI2- connected to GND). Ready for 3.3 V and 5 V logic.
Recommended frequency range	500 Hz to 20 kHz
Maximum frequency range	250 Hz to 50 kHz
Minimum detectable pulse width	200 ns

Next Figure shows the circuit model for the PWM encoder input. The PWM input can work perfectly with 5 V or 3.3 V logic signals. Just connect the negative input to GND.



PWM encoder modes

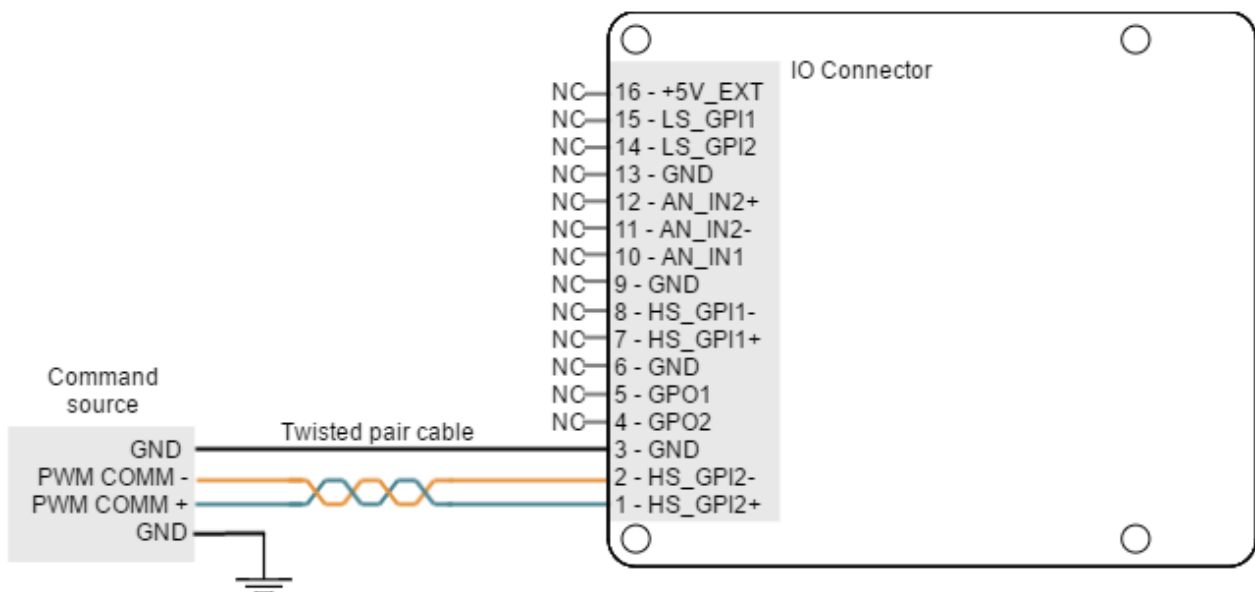
There are two different working modes for this command source:

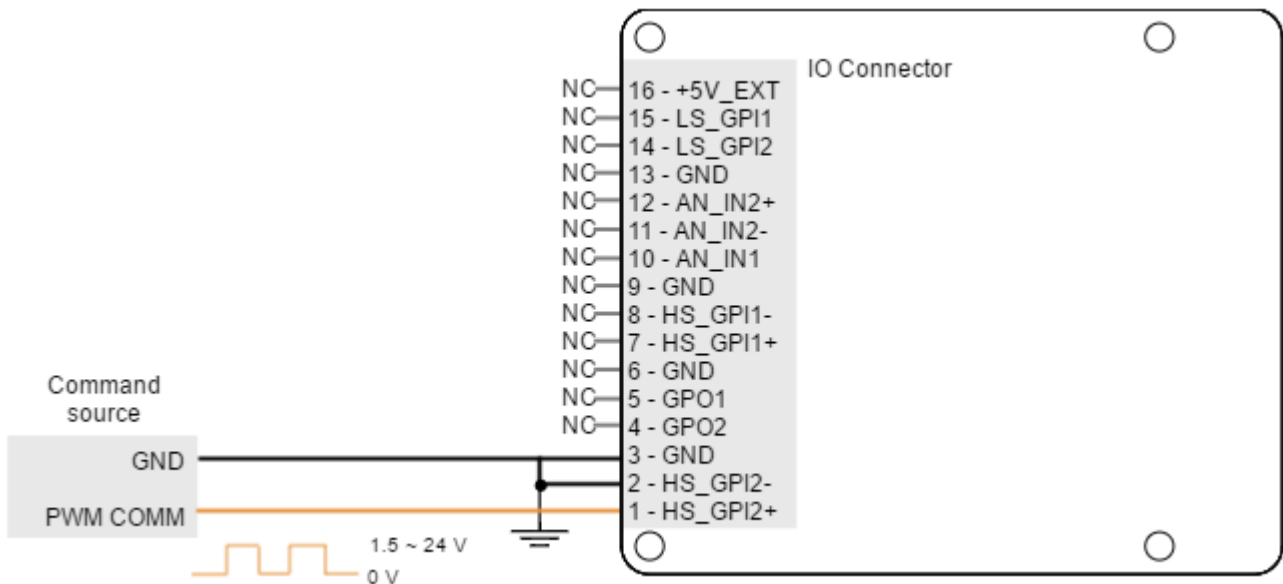
Single input mode

In this mode, only one input signal is used. PWM command is a PWM signal whose duty cycle sets the target position, velocity or torque.

For velocity mode, a duty cycle of 50% corresponds with 0 rpm. A 0% duty cycle corresponds with the maximum velocity in one direction, and a 100% duty corresponds to the maximum velocity in the opposite direction. Position and torque modes work in a similar way.

This mode uses High speed digital input 2. Refer to [Connectors](#) for information about connector's position and pinout, and see [High-speed \(HS\) digital inputs interface](#) for more information about digital inputs. Next figure shows how to connect this input:





Dual input mode

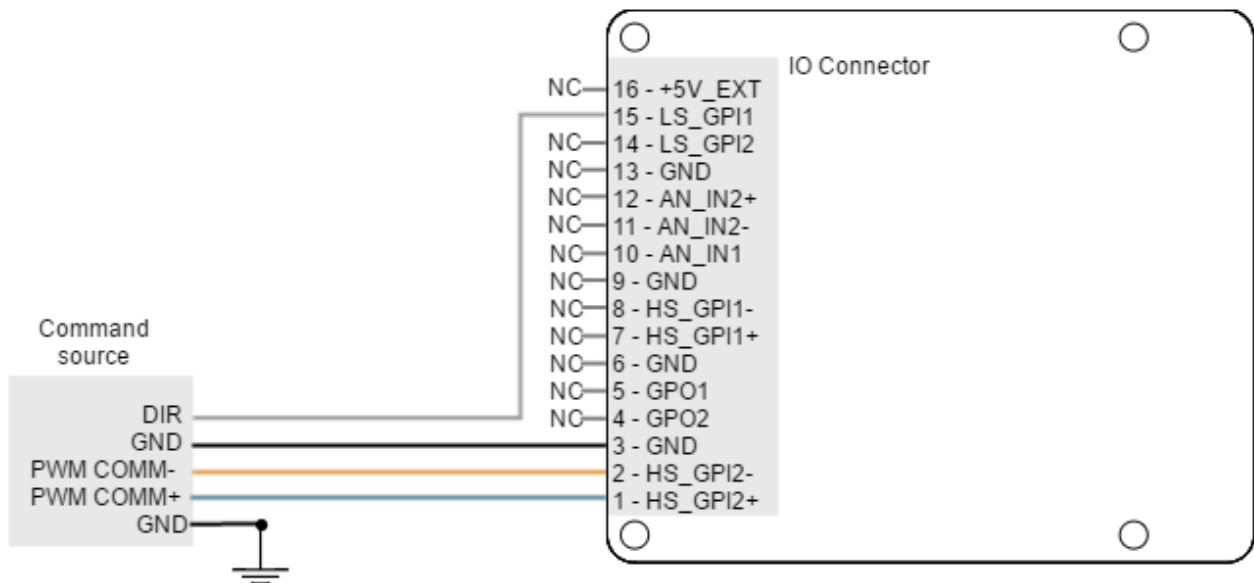
For this mode two signals are used. Direction signal sets the direction of rotation (for example "logic 0" for clockwise rotation and a "logic 1" for counter clockwise rotation). PWM command signal's duty cycle sets the target position, velocity or torque.

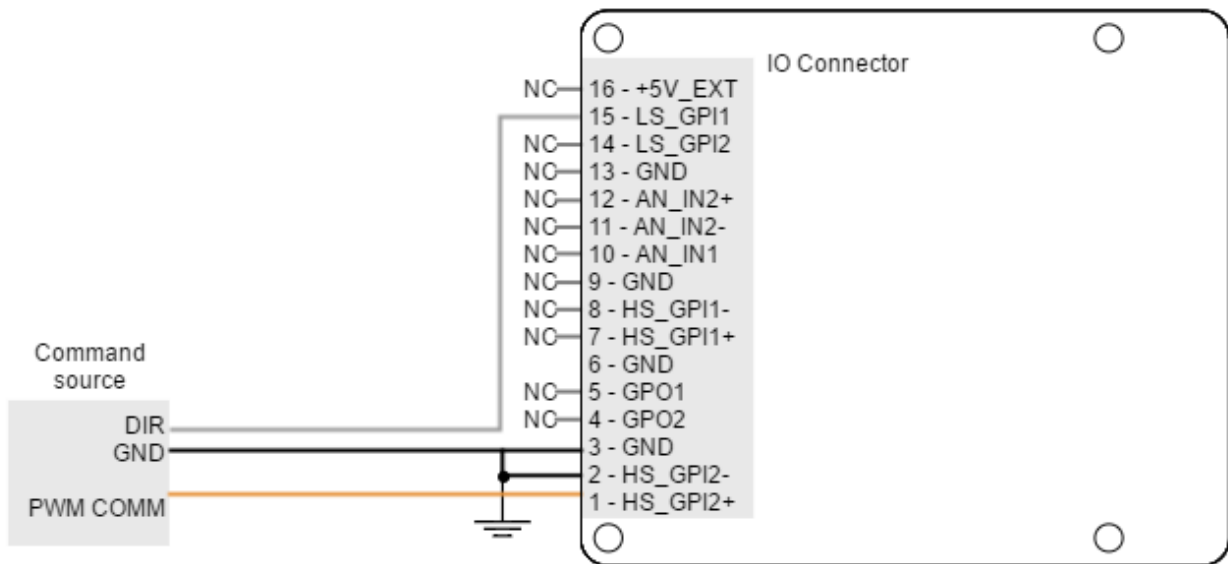
For velocity mode, a 0% duty corresponds with 0 rpm, and a 100% duty corresponds with maximum velocity. The direction of rotation depends on the value of the Direction signal. Position and torque modes work in a similar way.

Dual input mode uses two general purpose inputs:

- High speed digital input 2 for PWM Command
- Low speed digital input 1 for Direction.

Refer to [Connectors](#) for information about connector´s position and pinout, and see [High-speed \(HS\) digital inputs interface](#) and [Low-speed \(LS\) single ended digital inputs interface](#) for more information about digital inputs. Next figures show how to connect these inputs:



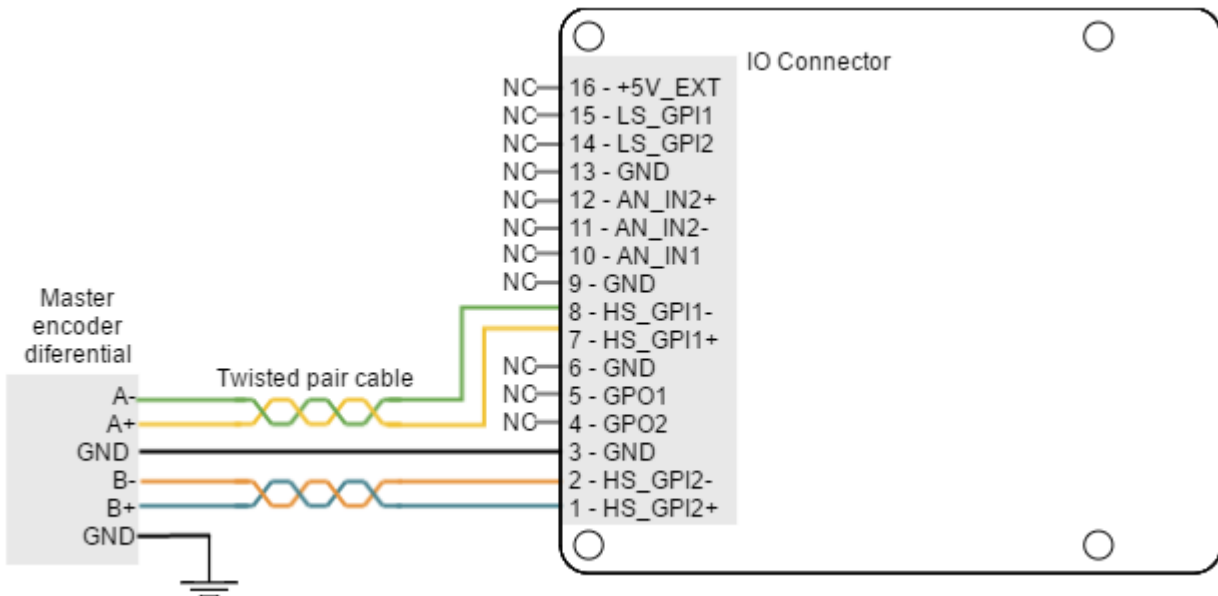


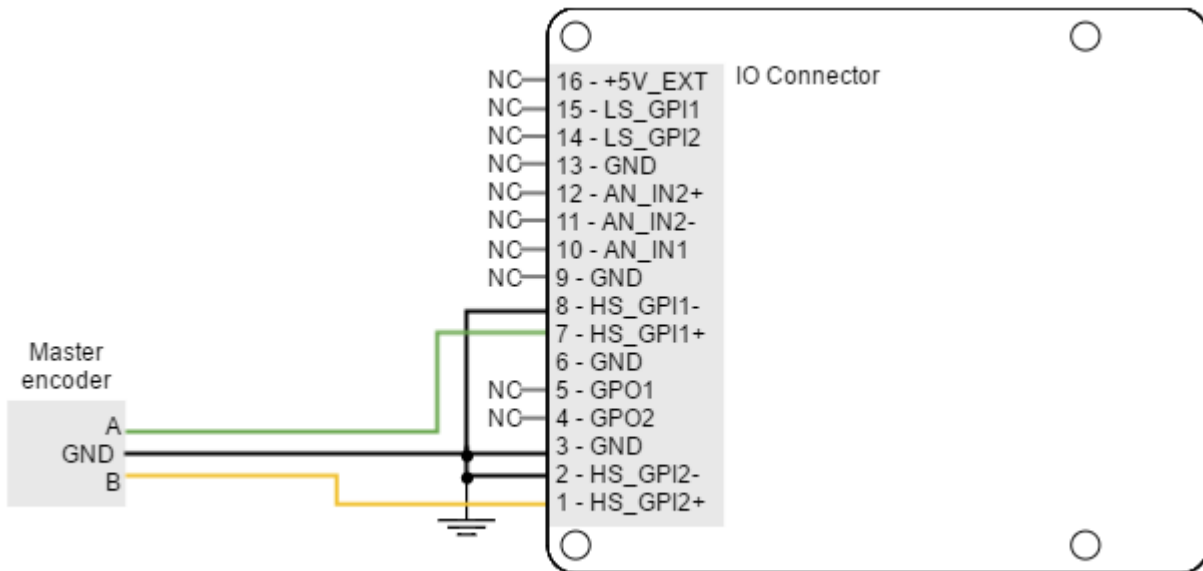
6.5.6 Encoder following or electronic gearing

Hydra can use encoder following as form of input command.

In encoder following mode, an auxiliary encoder signal can be used to command the drive in a master/slave configuration. The gearing ratio (input counts to output counts ratio) can be configured via software.

Encoder Following is only a valid option when the Hydra Servo drive is operated in position mode. The auxiliary encoder signal input should be connected to high speed digital input pins. Master encoder channel A must be connected to high speed digital input 1, and channel B will be connected to high speed digital input 2, as shown in next figures:





Refer to [Connectors](#) for information about connectors position and pinout, and see [High-speed \(HS\) digital inputs interface](#).

6.6 Communications

The Hydra Servo Drive provides different network communication interfaces for configuration and operation.

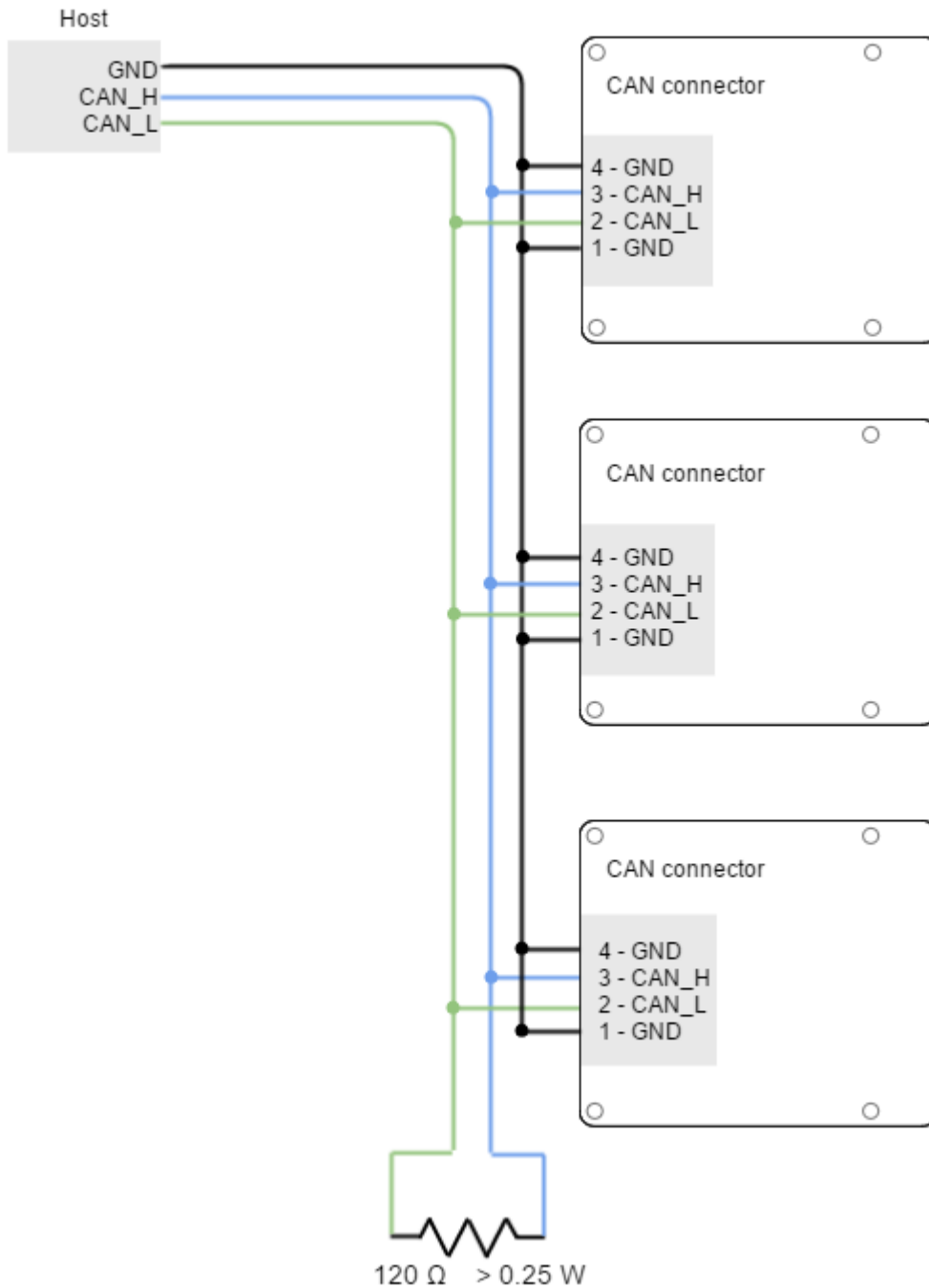
All the interfaces can be used to connect any of the supplied software applications or a custom application built with the supplied libraries for the controller. For ease of setup and diagnostics of CAN communication, USB and CANopen can be used simultaneously.

The communications connectors position and pinout are described in [Connectors](#).

6.6.1 CAN interface

Hydra Servo drive supports CAN-Bus (Controller Area Network-Bus), a serial communication protocol developed by Bosch for exchanging information between electronic control units on automobiles. Next table shows [CAN interface pins](#) specifications:

Specification	Details
Baud rate	from 125 kbps to 1 Mbps (default value)
Maximum number of nodes	64
Interface	Non-isolated
Common mode voltage	up to 48 V



Bus termination resistors (120 Ω between CANL and CANH at both ends of the bus) is essential for correct operation of the CAN bus (mainly for long distances and high baud rates).

✔ Termination jumper

A jumper placed above the CAN connector allows the user to terminate the bus with a 120 Ω resistor. Use a standard 2.54 mm pitch jumper for this purpose.

✔ GND and SHIELD

It is preferred to connect both GND pins (1 and 4) although it is not mandatory. The GND line in CANopen devices basically equals potentials between the master and the slaves but is not used for data transmission as the line is fully differential.

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

CAN wiring

Following are some relevant wiring good practices.

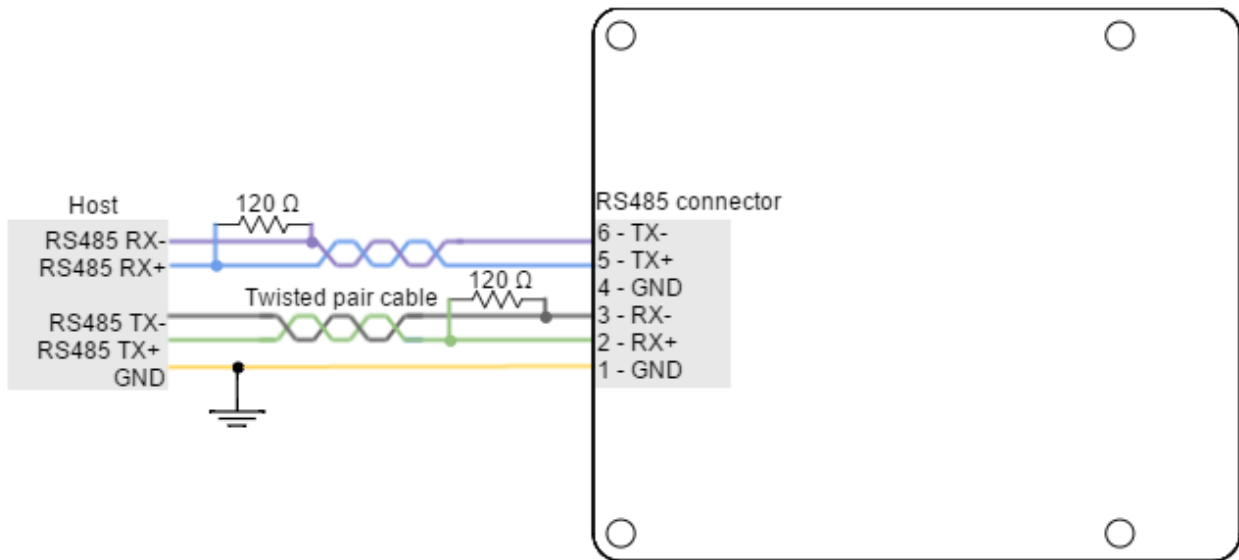
1. Build CAN network using cables with 2-pairs of twisted wires (2 wires/pair) as follows: one pair for CAN_H with CAN_L and the other pair for CAN_V+ with CAN_GND. The cable impedance must be 105 ... 135 Ω (120 Ω typical) and a capacitance below 30 pF/meter.
2. When total CAN bus length is over 40 meters, it is mandatory to use shielded twisted cables. Connect the cable shield to earth/shield.
3. Whenever possible, use bus links between the CAN nodes. Avoid using stubs. A stub is a "T" connection, where a derivation is taken from the main bus. When stubs can't be avoided keep them as short as possible. For 1 Mbit/s (worst case), the maximum stub length must be below 0.3 meters.
4. Connect the shield to the ground of the host (PC). Usually, this connection is soldered internally inside the connector at the PC end.
5. Ensure that the shield of the cable is connected to the shield of the connector used for communications.
6. If cable is long (>5 m) it is recommended to connect protective earth at both ends.

6.6.2 RS485 interface

The Hydra Servo Drive supports full duplex RS-485. Following table shows [RS485 interface connector](#) specifications:

Specification	Details
Communication distance	Up to 1200 m
Baud rate	100 to 10000 kbps
Channel type	Full duplex
Interface	Non-isolated
Daisy chain	Supported
Termination	120 Ω , not included on board

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



⚠ A 120 Ω termination resistor should be placed at the end of each differential pair bus. Suggested termination resistor: Xicon [271-120-RC](#).

Multiple drives full duplex connection

i Multiple drives configuration must be previously configured using MotionLab. Please set the UART configuration parameter [0x2000 - UART configuration](#) sub-index 0x03 to 1.

Next figure shows how to connect several Hydra Servo Drives.

⚠ A 120 Ω termination resistor should be placed at the end of each differential pair bus. Suggested termination resistor: Xicon [271-120-RC](#).

6.6.3 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 [USB connector](#) specifications:

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

✔ USB interface is recommended just for configuration purposes. CANopen option is strongly recommended in noisy environments.

USB power

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 [Supply and shunt connector](#). 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 driver is not capable of driving a motor or sensing a feedback input due to USB power limitations.

USB wiring recommendations

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

1. Use shielded cable with the shield connected to PC end. Shield of micro USB connector is not connected on Hydra.
2. Do not rely on an earthed PC to provide the Hydra Servo Drive earth connection. The drive must be earthed through a separate circuit.
3. Avoid creating ground loops.

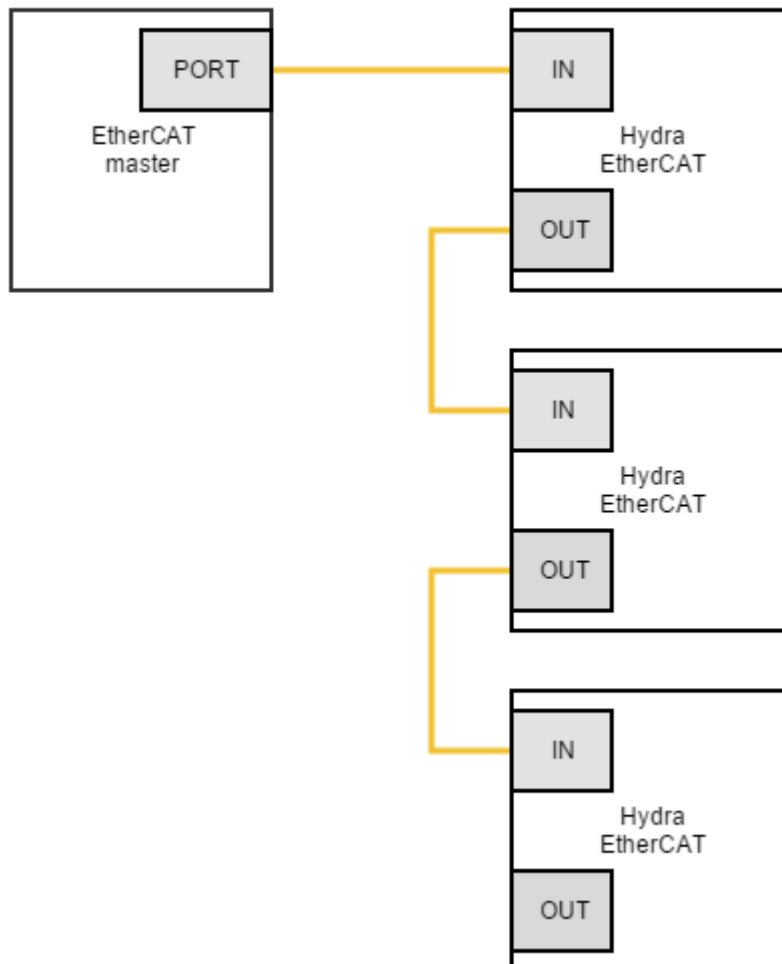
6.6.4 EtherCAT interface

Hydra Servo Drive EtherCAT variant provides access to the EtherCAT fieldbus system, suitable for hard and soft real-time requirements in automation technology, test and measurement and many other applications.

EtherCAT specific features	
Ports available	2
LED Signals	Status LED
	Link/Act LED
Supported Mailbox	CoE
<i>SDO info</i>	Not supported
<i>Segmented SDO</i>	Supported
<i>SDO complete access</i>	Not supported
Modes of operation	DS402 drive device profile
	Open loop (vector & scala
	Velocity Mode
	Profile torque
	Profile velocity
	Profile position

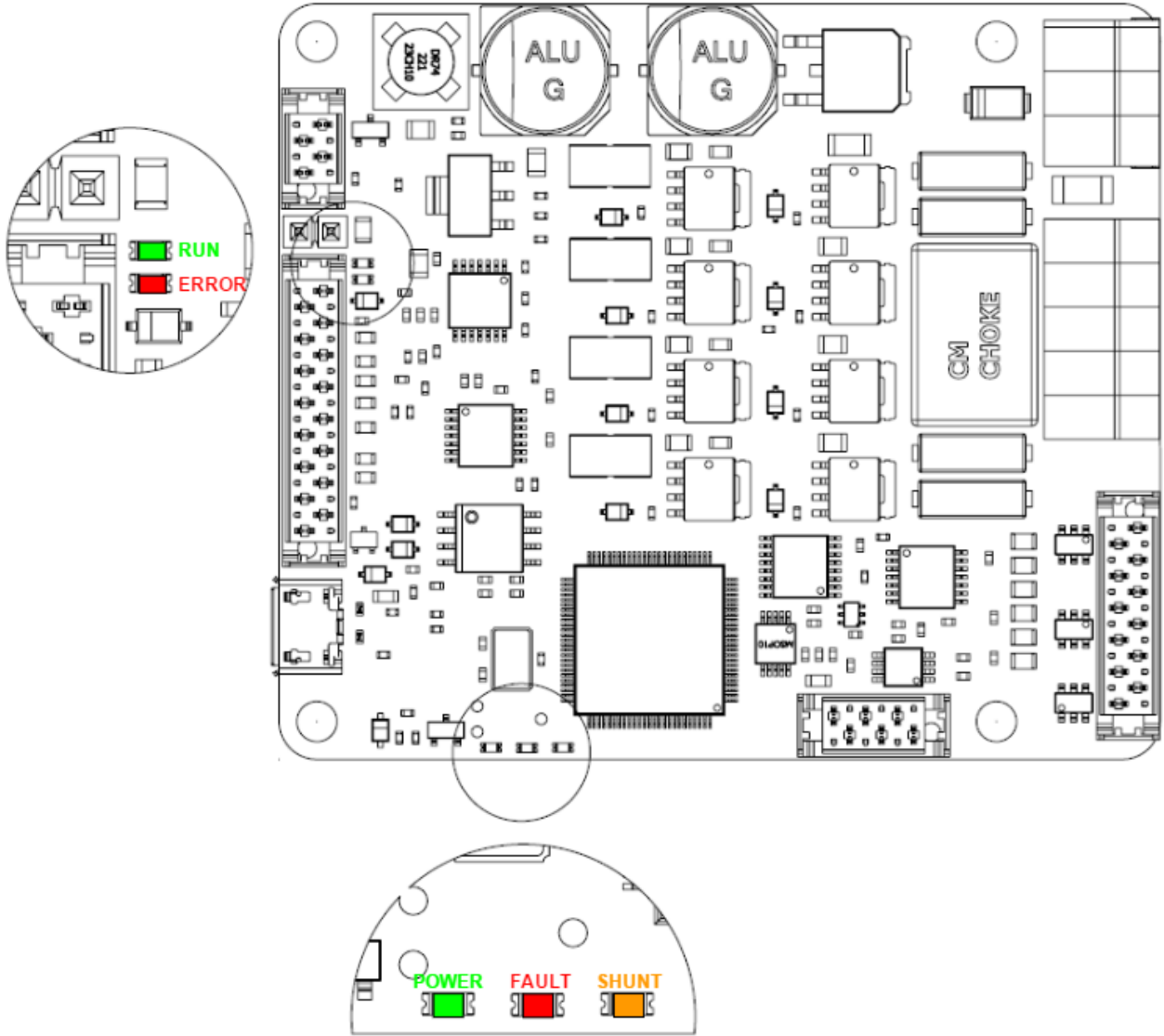
EtherCAT specific features	Homing modes
	Interpolated position mode
	Cyclic synchronous position mode (<i>Update rate up to 1 ms</i>)
	Cyclic synchronous velocity mode (<i>Update rate up to 1 ms</i>)
	Cyclic synchronous torque mode (<i>Update rate up to 100 us</i>)
Synchronization modes	Free Run
	Distributed clock (<i>Cyclic modes</i>)
Process data object	Configurable, up to 64 objects

Next figure shows how to connect the Hydra EtherCAT in an EtherCAT bus.



7 Signalling LEDs

Hydra Servo Drive has 5 signalling LEDs near the CAN interface connector and USB connector.



7.1 Power and motor signalling LEDs

Next table shows the meaning of each motor and power 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 PWM signal and indicates that maximum user voltage has been exceeded and Shunt is enabled.

7.2 CAN signalling LEDs

There are 2 LEDs besides the CAN interface connector. These LEDs provide information regarding communication status according to CANopen [CiA 303-3 recommendations](#). The Red LED is **ERROR LED** and green one is **RUN LED**.

The CANopen ERROR LED indicates the status of the CAN physical layer and errors due to missing CAN messages (sync, guard or heartbeat). Next table shows the CANopen ERROR LED truth table:

ERROR LED	State *	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 NMTmaster) 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

The CANopen RUN LED indicates the status of the CANopen network state machine. Next table shows the CANopen RUN LED truth table:

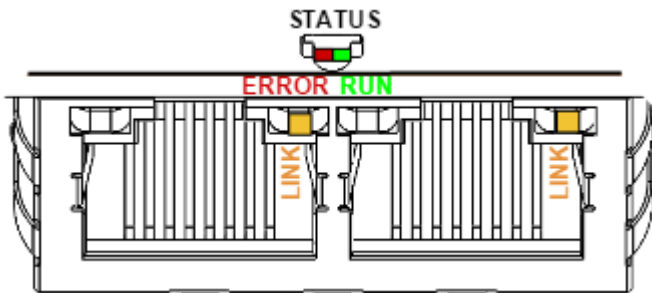
RUN LED	State *	Description
Off	Off	The device is switched off
Blinking	Pre-operational	The device is in state PREOPERATIONAL
Single flash	Stopped	The device is in state STOPPED
On	Operational	The device is in state OPERATIONAL

See the description of the states next:

* 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.

7.3 EtherCAT signalling LEDs

The EtherCAT variant of the Hydra has 3 LEDs to indicate the board status.



7.3.1 EtherCAT status LED

The EtherCAT Plug-in Board has a bicolor GREEN / RED LED. The Green LED is the RUN LED, and the Red LED is the ERROR LED.

Next table shows the EtherCAT LEDs truth table, which indicates the status of the EtherCAT state machine.

RUN LED	Slave State	ERROR LED	Slave State
Off	INIT	Off	No error
Blinking	PRE-OPERATIONAL	Blinking	Invalid configuration
Single Flash	SAFE-OPERATIONAL	Single flash	Local error
On	OPERATIONAL	Double flash	Watchdog timeout
		On	Application controller failure

If a high severity error occurs inside the motion controller, an special LED signalling has been developed:

Error identification	Signalling	RUN LED	ERROR LED
INTERNAL ERROR	Interleaved blink	Blinking (Initial status: OFF)	Blinking (Initial status: ON)



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

7.3.2 EtherCAT in-connector LED

Every EtherCAT connector has two LEDs, but only the Yelow LED is used, which indicates the state of the physical link activity on this port:

LINK LED	Slave State
Off	Port closed
Flickering	Port opened (activity on port)
On	Port opened (no activy on port)

8 Software

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

<http://ingeniamc.com/software#motionlab>

If you want to make your own application to communicate with the Hydra you can use the **multiplatform library MCLIB**:

<http://ingeniamc.com/software#mclib>

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

<http://ingeniamc.com/software#ardulib>



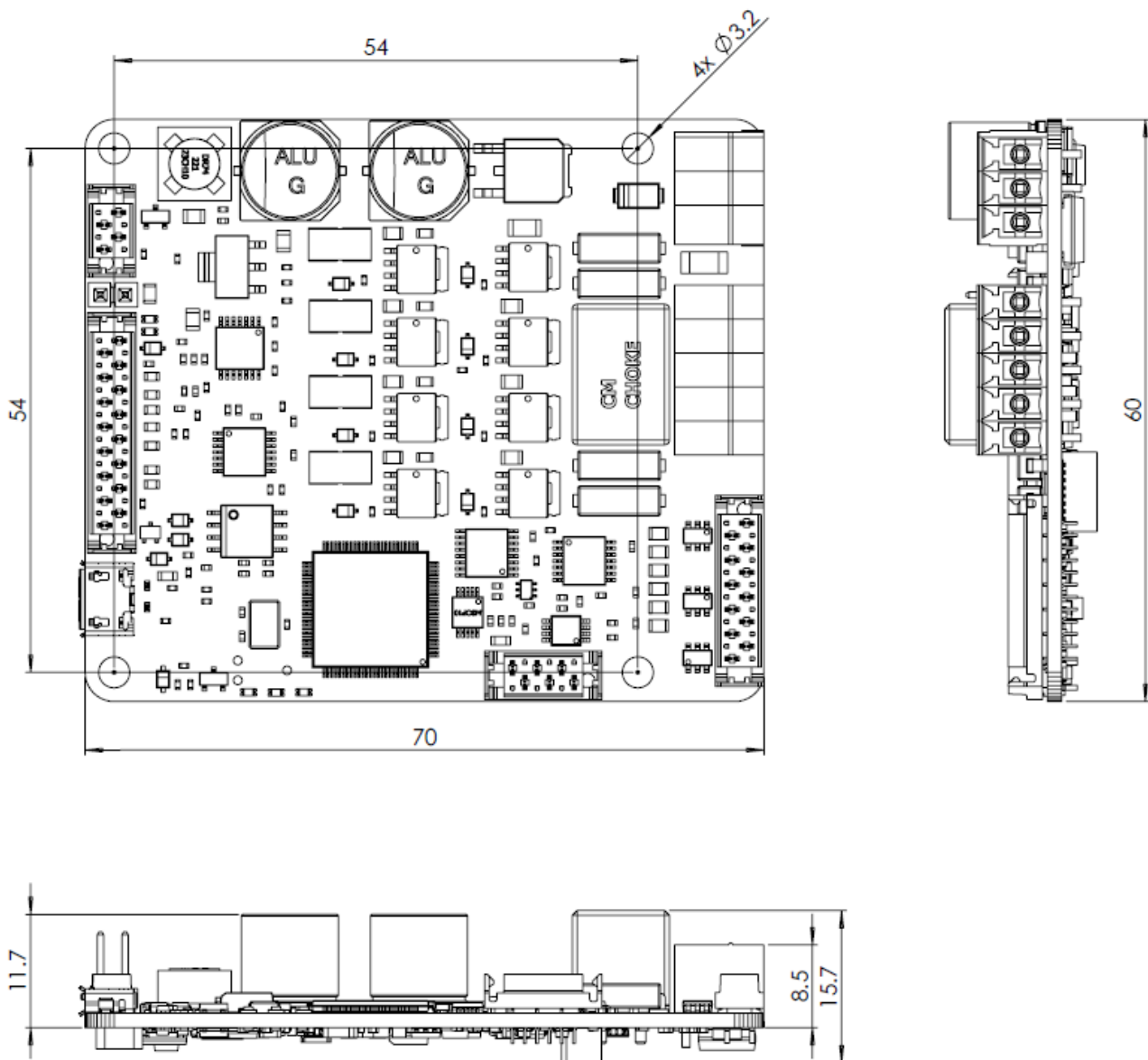
Before configuring your drive for a new application make sure you have upgraded your drive to the latest firmware revision. You can do it with Motion Lab.

9 Dimensions

9.1 Standard version

Hydra Servo Drive has a 60 mm x 70 mm footprint and a maximum 15.7 mm height. The driver is provided with 4 x $\varnothing 3.2$ mm holes for M3 standoff mounting as well as to allow mounting the [EtherCAT Daughter Board](#) and the [IO Starter Kit](#). 3D models can be downloaded [here](#).

Next figure shows mechanical dimensions in mm. Tolerances $\leq \pm 0.2$ mm.



⚠ Fixation elements diameter ≤ 6 mm

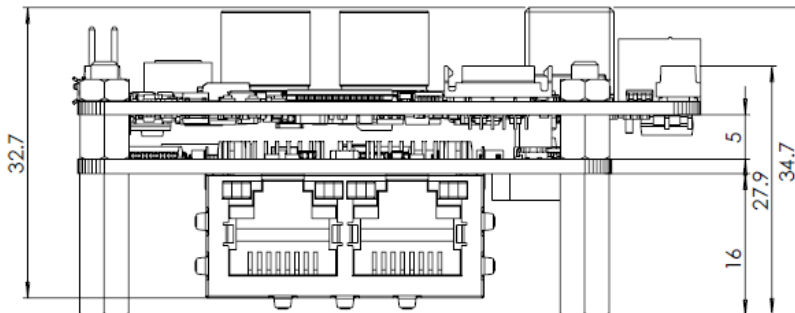
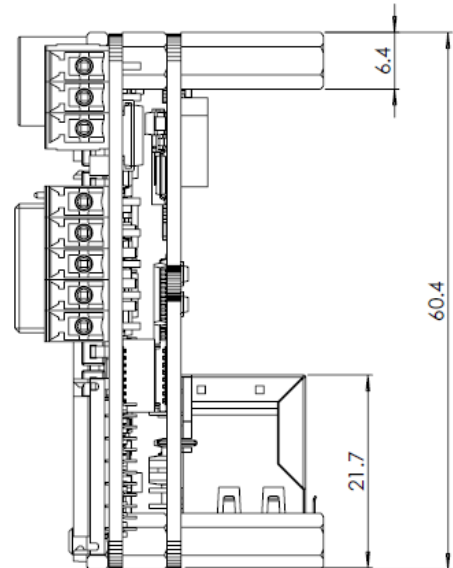
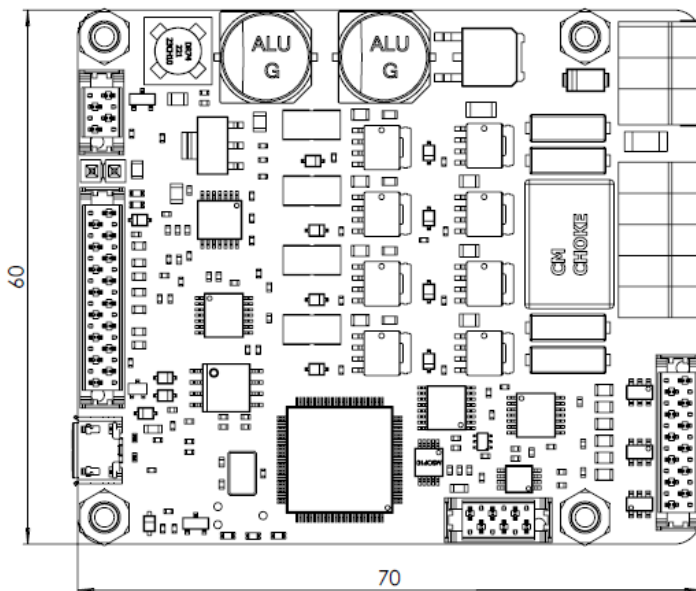
Please do not use spacers, washers or nuts exceeding 6 mm external diameter as they could collide with some electrical parts.

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

9.2 EtherCAT version

Hydra EtherCAT version has a 60 mm x 70 mm footprint and a maximum 34.7 mm height. The driver is provided with 4 x M3 standoff. 2 RJ45 connectors allow the user to use EtherCAT as a communication protocol. See [EtherCAT Plug-in Board](#) for more details. 3D models can be downloaded [here](#).

Next figure shows mechanical dimensions in mm. Tolerances $\leq \pm 0.2$ mm.



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