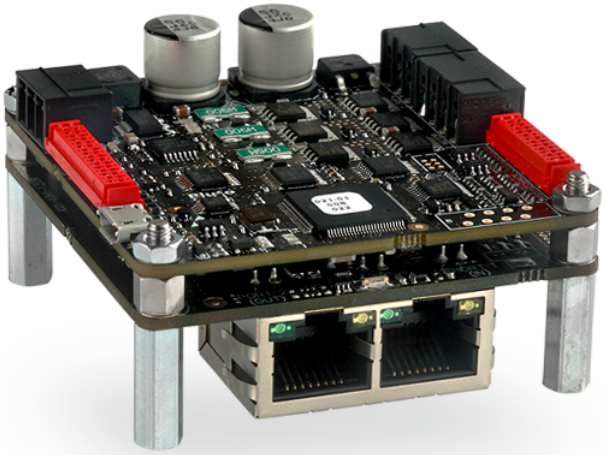
Pluto Product Manual



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INGENIA
passion for motion

1 Table of Contents

2 General Information

2.1 Manual revision history

Revision	Release Date	Changes	
v1	January 2013	Initial Version. For Pluto 1.0.0B1 and 1.0.1R.	
v2	April 2014	Update for hardware revision 1.1.0R	
v3	March 2016	Several improvements after revision 2.0.1R	
v4	April 2016	Added EtherCAT information. Structure improvements.	
v5	November 2016	Minor improvements.	
v6	March 2017	Aesthetics and structure improvements. Wiring information improved.	
v7	May 2017	Improved PDF export format.	
v8	February 2020	Minor corrections. Added automated PDF exporter.	
v9	October 2020	Added changes for Pluto revision 3.0.	Download PDF

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

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3 Safety Information

3.1 About this manual

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

To ensure maximum safety in operating the Pluto 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 Pluto 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.

3.2 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 Pluto 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 Pluto 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).

3.3 Precautions

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

- The Pluto Servo Drive components temperature may exceed 100 ^{o}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 Pluto 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 Pluto Servo Drive, check that all safety precautions have been followed, as well as the installation procedures.

4 Product Description

Pluto is a high performance closed-loop servo drive controller suitable for DC brushed, voice coils, and brushless motors and supports trapezoidal and sinusoidal commutation.

The drive is available with EtherCAT and CANopen interfaces, enabling a wide choice of interfacing methods. From version 3.0 onwards, the CANopen is rugged and fully isolated. It can also be accessed from USB. Its extended voltage operating range up to 60 V 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.

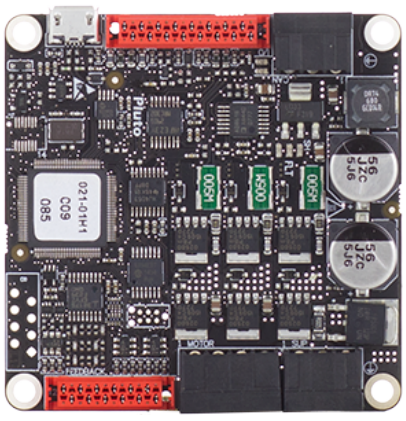
The design also includes a wide variety of self-protection mechanisms making it a reliable option for your motor control application.

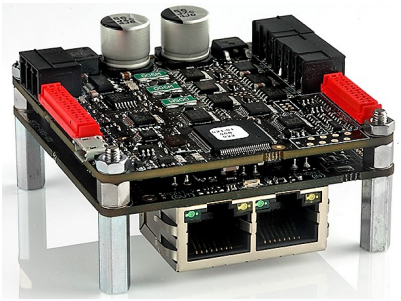
4.1 Pluto part numbering

PLU-x/xx-y

Power rating:
1/48 = 1 A cont / 2 A peak @ 48V nominal
5/48 = 5 A cont / 10 A peak @ 48V nominal
8/48 = 8 A cont / 16 A peak @ 48 V nominal

Communication interfaces:
C = USB/CANopen
E = USB/EtherCAT

Ordering part number	Status	Image
PLU-1/48-C	OBSOLETE	
PLU-5/48-C	OBSOLETE	
PLU-8/48-C	ON DEMAND	

Ordering part number	Status	Image
PLU-1/48-E	OBSOLETE	
PLU-5/48-E	OBSOLETE	
PLU-8/48-E	OBSOLETE	

Legacy Part Numbers

Part numbers have changed from Pluto Manual version 4. Follow this equivalence to identify your old Pluto:

- PLU-HS → PLU-1/48-y
- PLU-STD → PLU-5/48-y
- PLU-EXT → PLU-8/48-y

4.2 Specifications

Electrical and power specifications			
Part number →	**PLU-1/48-y**	**PLU-5/48-y**	**PLU-8/48-y**
Nominal power supply voltage	10 V_{DC} to 48 V_{DC} (Current ratings and nominal performance is given at this range.)		
Maximum continuous power supply voltage	59 V_{DC} (For revisions **2.1.1** onward), 53 V_{DC} (For **2.1.0** and previous revisions)		
Transient peak power supply voltage	62.5 V @ 100 ms (For revisions **2.1.1** onward), 60 V @ 100 ms (For **2.1.0** and previous revisions)		
Logic supply voltage	Not needed, supplied from Power supply voltage		
Internal DC bus capacitance	112 µF		
Minimum motor inductance	200 µH		
Nominal phase continuous current	1 A_{RMS}	5 A_{RMS}	8 A_{RMS}

Maximum phase peak current	2 A_{RMS} (5 s)	10 A_{RMS} (5 s)	16 A_{RMS} (5 s)
Current sense range	± 4.8 A	± 19.2 A	± 32 A
Current sense resolution	9.35 mA/count	37.39 mA/count	62.32 mA/count
Shunt braking transistor	Shunt braking transistor on board. 16 A maximum current. Dimensioning a Shunt Resistor for Regenerative Braking		
Cold plate	No		
Power connectors	Pluggable terminal block 3.5 mm pitch		
Standby power consumption	1.5 W (max). 2 W EtherCAT version (PLU-x/xx-E)		
Efficiency	> 97% at the rated power and current		
Motion control specifications			
Motion control core	Ingenia E-Core with EMCL2.		
Supported motor types	• Rotary brushless (trapezoidal and sinusoidal) • Linear brushless (trapezoidal and sinusoidal) • DC brushed • Rotary voice coil • Linear voice coil		
Power stage PWM frequency	40 kHz (default) 20 kHz (alternative PWM frequency, configurable)		
Current sensing	On phases A, B and C using 4 terminal kelvin shunt resistors. Accuracy is ± 1% full scale. 10 bit ADC resolution.		
Sensors for commutation (brushless motors)	• Digital halls (Trapezoidal) • Analog halls (Sinusoidal / Trapezoidal) • Quad. Incremental encoder differential and single-ended (Sinusoidal / Trapezoidal) • PWM encoder (Sinusoidal / Trapezoidal) • Analog potentiometer (Sinusoidal / Trapezoidal) ⓘ Pluto does not allow Sin-Cos encoder. For a drive with similar form factor power and Sin-Cos encoder see the Nix Servo Drive.		

Sensors supported for servo loops	• Digital halls • Analog halls • Quadr. Incremental encoder • PWM encoder • Analog potentiometer • DC tachometer
Supported target sources	• Network communication – USB • Network communication – CANopen • Network communication – EtherCAT • 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. (24V 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
	• Hall sequence/combination error
	• ESD protections in all inputs, outputs, feedbacks and communications.
	• EMI protections (noise filters) in all inputs, outputs and feedbacks.
	• Inverse polarity supply protection (bidirectional)
	• High power transient voltage suppressor for short braking (1500 W peak TVS diode).

Motor brake	Motor brake output through GPO1 or GPO2. Up to 24 V and 1 A.
Communications	

USB	µUSB (2.0) connector.	
CANopen	1.x.x and 2.x.x. versions: **Non-isolated**	CiA-301, CiA-305 and CiA-402 compliant. Maximum baud rate of 1 Mbps. Not isolated. 120 Ω termination not included on board.
	3.0 and next versions: **Isolated**	CiA-301, CiA-305 and CiA-402 compliant. Maximum baud rate of 1 Mbps. Robust bus fault tolerant up to ±65 V between CANH, CANL and CAN_GND_ISO. Galvanic insulation, Maximum 1500 V DC voltage. 120 Ω termination not included onboard.
EtherCAT	Available on PLU-x/yy-E versions.	
Environmental and mechanical specifications		
Ambient air temperature	• -40 °C to +50 °C full current (operating) • +50 °C to +100 °C current derating (operating) • -40 to +125 °C (storage)	
Maximum humidity	5% - 85% (non-condensing)	
Dimensions	60 mm x 60 mm x 15 mm	
Weight (exc. mating connectors)	35 g	

4.3 Hardware revisions

Hardware revision*	Description and changes
1.0.1R	First product release.

Hardware revision*	Description and changes
1.1.0R	• CAN connector change from 4 ways to 3 ways (Phoenix Contact 1937509). PE pin is removed from connector. PE connection should be made with the plated mounting holes • CAN LEDs position change • Supply connector change from 4 ways to 3 ways (Phoenix Contact 1937509). PE pin is removed from connector. PE connection should be made with the plated mounting holes • IO connector change TE Micro-Match model 8-188275-6. Same pinout except one change: +5.0 V output is added at pin 16. (Version 1.0.1 had this pin connected to GND) • Feedback connector change to TE Micro-Match model 8-188275-2. Pinout remains identical to version 1.0.1R • Increased USB port electrical robustness and noise immunity • Readjusted power stage elements to minimize electromagnetic emissions
2.0.1R	• Added EtherCAT connectivity • PCB and PCA modifications to improve manufacturing reliability • Changed rounded corners radius for aesthetic reasons • High-speed (HS) digital inputs interface are pre-biased to allow easy wiring in single ended applications • Added STO (Safe Torque Off) as a mounting option upon demand
2.1.0	• Manufacturing improvements and component upgrades • Improvements on power stage transistors to minimize losses in all versions • Removed unnecessary components • CAN connector changed to FCI 20020110-C031A01LF (green) to avoid confusion with the supply and shunt connector • Silkscreen improvements
2.1.1	• Upgraded maximum supply voltage to 59 V.
3.0	• Added galvanic isolation to CAN interface to improve electrical safety and common mode noise immunity • Protected CAN interface against accidental connection of power supply up to ±60 V to CANH and CANL • Added logic supply through USB • Reduced standby power consumption by 100 mW ~ 200 mW by changing linear regulators to high efficiency DC/DC • Manufacturing improvements and component upgrades

Identifying the hardware revision

*Hardware revision is screen printed on the board.

4.4 Power and current ratings

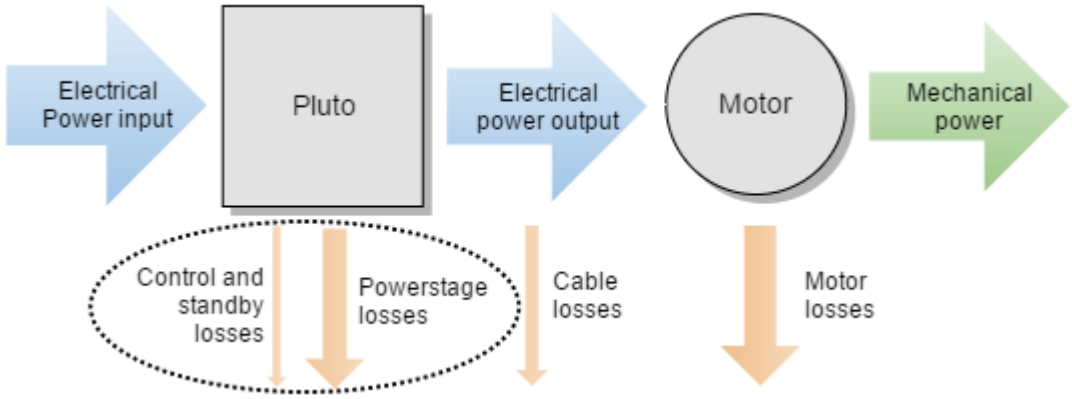
Pluto is capable of providing the nominal current from -40°C to 50°C ambient air temperature without the need of any additional heatsink or forced cooling system powered at 48 V. From 50°C to 80°C of ambient temperature a current derating is needed.

Excessive power losses lead to over temperature that will be detected and cause 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 or CAN interface does not indicate the air temperature. Above 110°C the Pluto automatically turns off the power stage and stay in fault state avoiding any damage to the drive. A Fault LED will be activated and cannot be reset unless temperature decreases.

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

Some parts of the Pluto exceed 100°C 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.

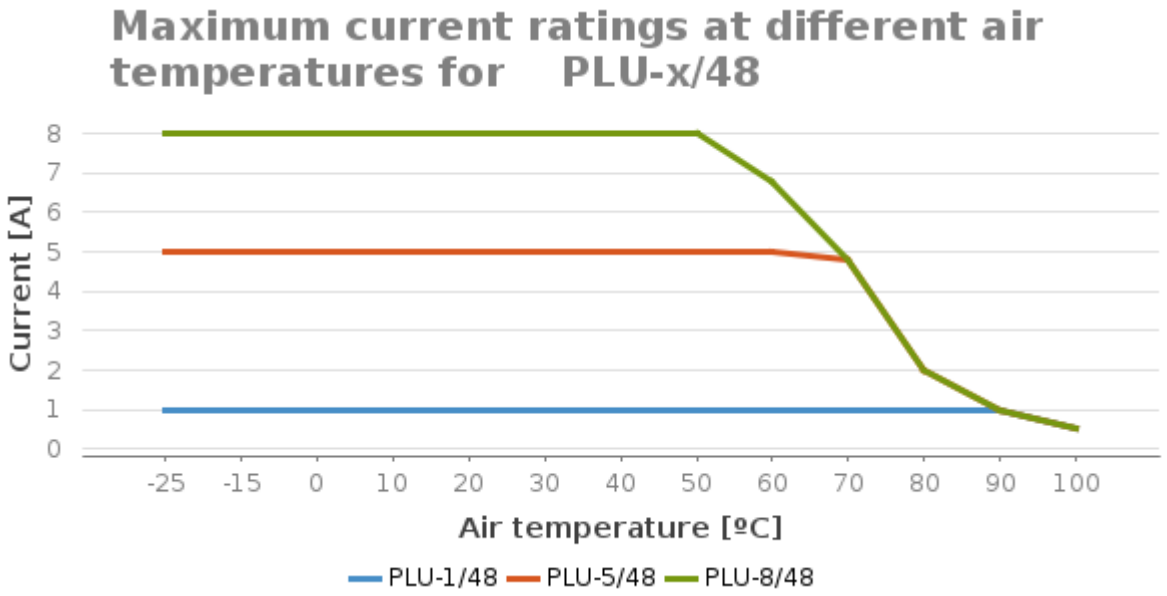


4.4.1 Current ratings

The Pluto 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< 110°C). The threshold temperature where the current derating should start depends on the DC bus voltage, available cooling and PWM frequency configuration.



Current derating

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

4.4.2 Dynamic application (non-constant current)

The Pluto 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.

I_1 is the current during t_1

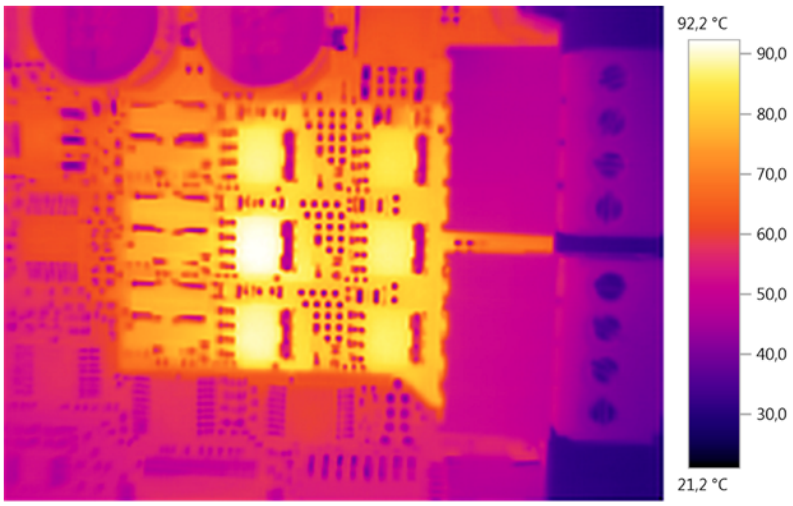
I_2 is the current during t_2

I_n is the current during t_n

4.4.3 System temperature

Next thermal image shows an example of the heat distribution in a the PLU-8/48-y. The test has been performed at maximum load and air temperature in a 3 phase application.

To improve the power performance of the drive a heatsink can be added on top of the power stage transistors with a thick (>1 mm) thermal interface material gap pad. This will extend the performance of the drive. For further details ask Ingenia Support.

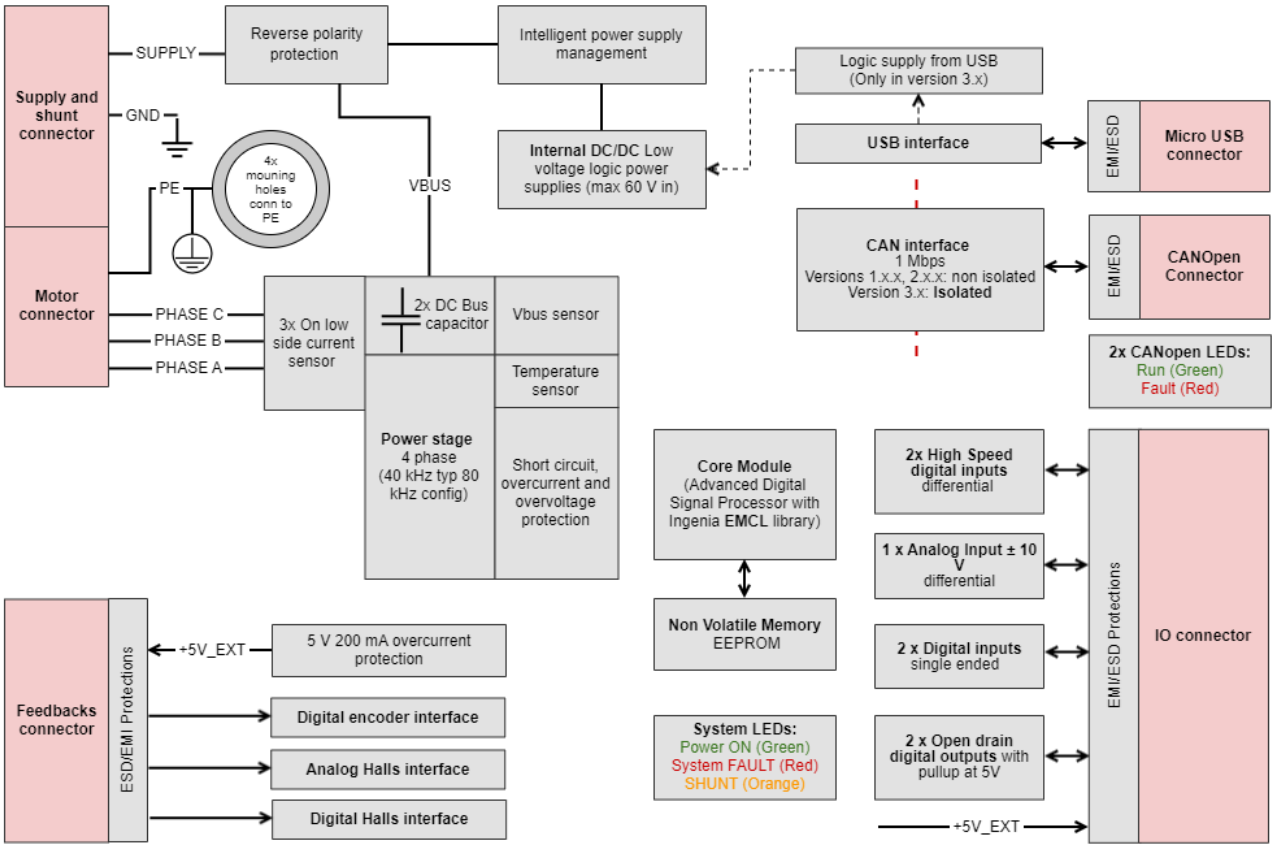


The drive is getting hot even at 0 current!

This is normal. Pluto 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 the motor is off, exit motor enable mode which will switch off the power stage.

4.4.4 Architecture

The following figure shows a simplified hardware architecture of the Pluto Servo Drive. Links provide direct access to relevant pages.

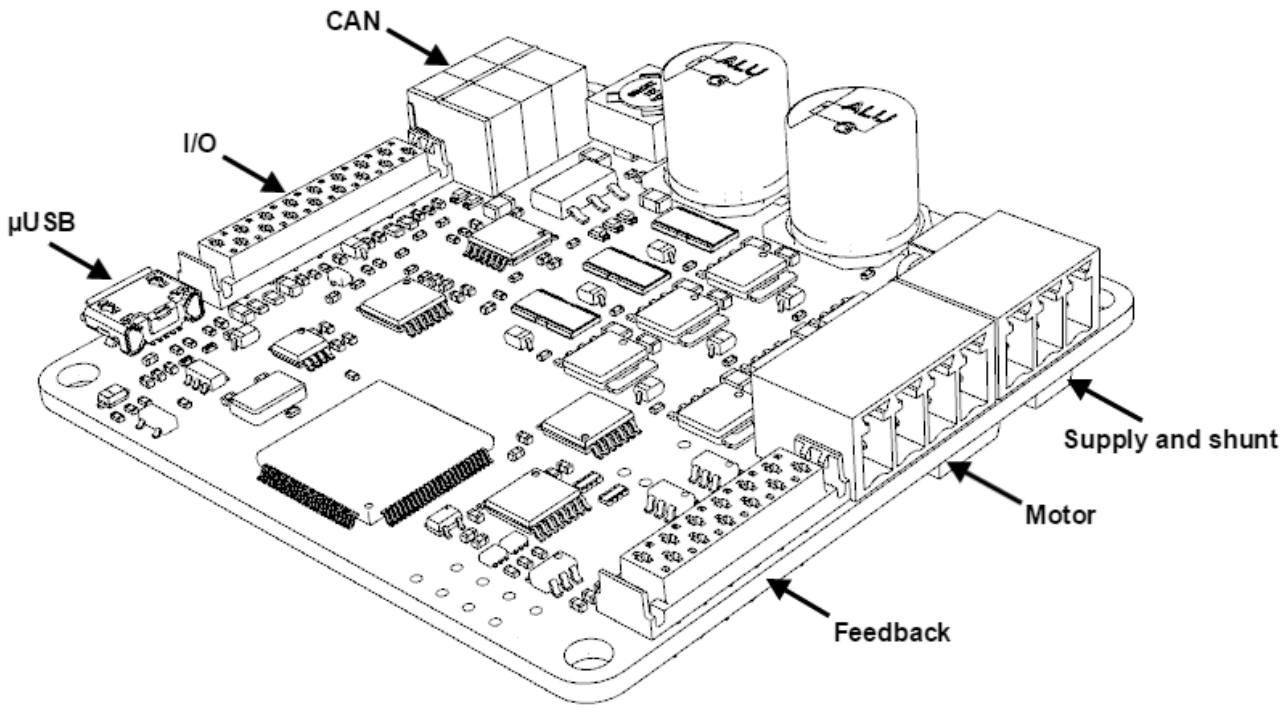

Supply and shunt connector
SUPPLY
GND
PE
4x mouning holes conn to PE
Reverse polarity protection
VBUS
Intelligent power supply management
Internal DC/DC Low voltage logic power supplies (max 60 V in)
Logic supply from USB (Only in version 3.x)
USB interface
EMI/ESD
Micro USB connector
CAN interface
1 Mbps
Versions 1.x.x, 2.x.x: non isolated
Version 3.x: Isolated
EMI/ESD
CANOpen Connector
2x CANopen LEDs:
Run (Green)
Fault (Red)
Motor connector
PHASE C
PHASE B
PHASE A
3x On low side current sensor
2x DC Bus capacitor
Vbus sensor
Temperature sensor
Power stage
4 phase
(40 kHz typ 80 kHz config)
Short circuit, overcurrent and overvoltage protection
Core Module
(Advanced Digital Signal Processor with Ingenia EMCL library)
Non Volatile Memory
EEPROM
System LEDs:
Power ON (Green)
System FAULT (Red)
SHUNT (Orange)
2x High Speed digital inputs
differential
1 x Analog Input ± 10 V
differential
2 x Digital inputs
single ended
2 x Open drain digital outputs with pullup at 5V
+5V_EXT
EMI/ESD Protections
IO connector
Feedbacks connector
ESD/EMI Protections
+5V_EXT
5 V 200 mA overcurrent protection
Digital encoder interface
Analog Halls interface
Digital Halls interface

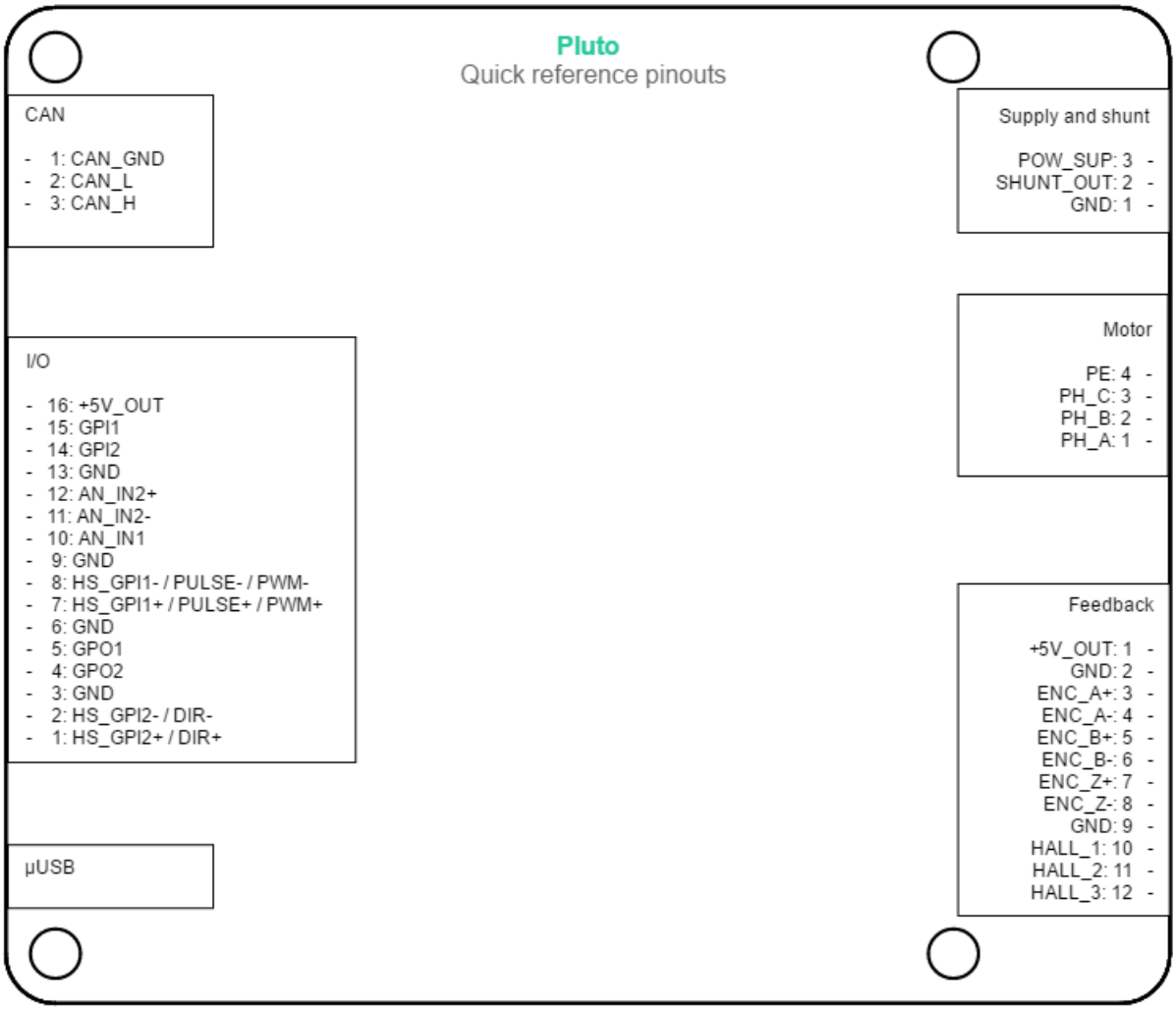
5 Connectors Guide

This chapter details the Pluto Servo Drive connectors and pinout. Two Pluto variants are detailed:

- Pluto with USB or USB/CANOpen (PLU-x/xx-S and PLU-x/xx-C).
- Pluto with EtherCAT (PLU-x/xx-E).

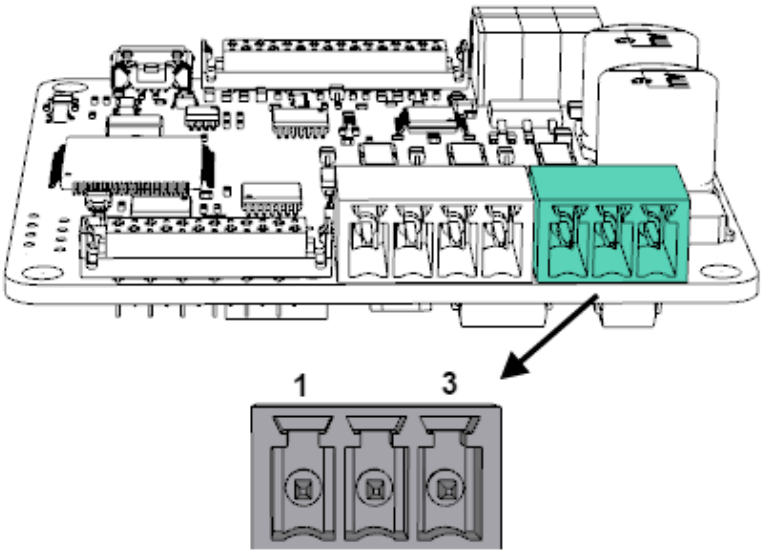
5.1 Connectors position and pinout of Pluto (PLU-x/xx-S and PLU-x/xx-C)





5.1.1 Supply and shunt connector

P1 Connector



3 position 3.5 mm pitch pluggable terminal block, black. MOLEX 39502-1003

Pin	Signal	Function
1	GND	Negative power supply input (Ground)
2	SHUNT_OUT	External shunt resistor connection
3	POW_SUP	Positive power supply input

Mating	
Description	Pluggable terminal block, 3 positions 3.5 mm pitch
Part number	MOLEX 395000003
Distributor codes	Arrow 395000003

Notes

- See Power supply 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 mm^2 ~ 1.5 mm^2

Do not confuse with CAN connector

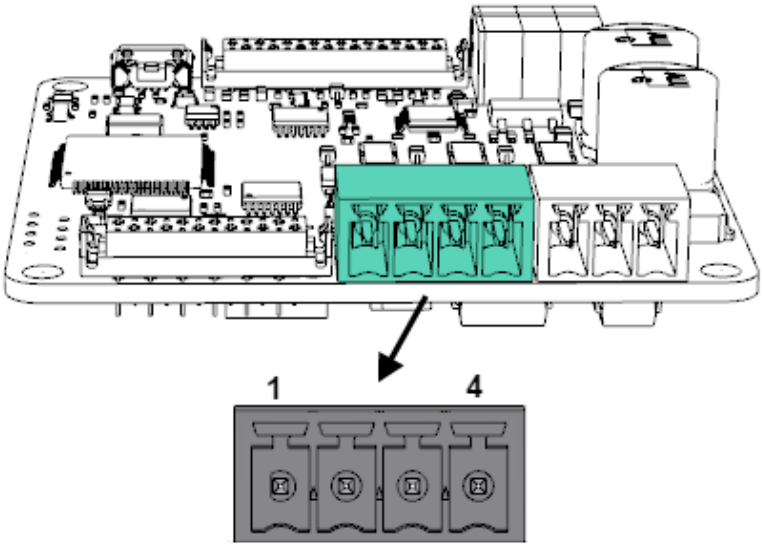
Please note that both CAN and Supply use the same type of connector, except for a difference of color: Supply and shunt connector is black and CAN connector is green. Please check you are connecting your power supply to the right connector.

Previous versions compatibility

Supply connector has changed from version 1.0.1R of Pluto Servo Drive. Please see Hardware revisions for more information.

5.1.2 Motor connector

P2 Connector



4 position 3.5 mm pitch pluggable terminal block, black. Molex 39502-1004

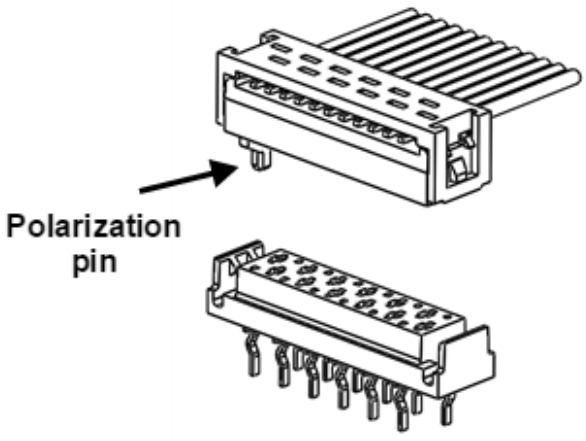
Pin	Signal	Function
1	PH_A	Motor phase A (Positive for DC and voice coils)
2	PH_B	Motor phase B (Negative for DC and voice coils)
3	PH_C	Motor phase C (Do not connect for DC and voice coils)
4	PE	Motor protective earth connection, internally connected to standoffs

Mating	
Description	Pluggable terminal block, 4 positions 3.5 mm pitch
Part number	Molex 39500-0004
Distributor codes	Digi-Key WM7734-ND Farnell 1368470 Mouser 538-39500-0004
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 mm^2 ~ 1.5 mm^2 • For wiring information, see motor and shunt braking resistor and protective earth wiring sections.	

5.1.3 Micro-Match connectors mating

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

5.1.3.1 Ribbon cable

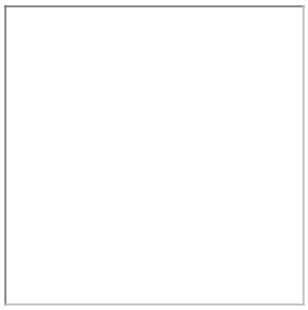
Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch
Image	
Cable	

Use 0.5 mm² (24 AWG) flat cable.

Easy wiring

Ribbon cable is the easiest and lowest cost option.

5.1.3.2 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
ImagePLU-151	
Part number	TE Connectivity 1-338097-1
Distributor codes	Farnell 1291807 Digi-Key A99491CT-ND Mouser 571-1-338097-1
Cable	
Use 0.2 ~ 0.5 mm² (20 ~24 AWG) flexible wires.	

Clean wiring

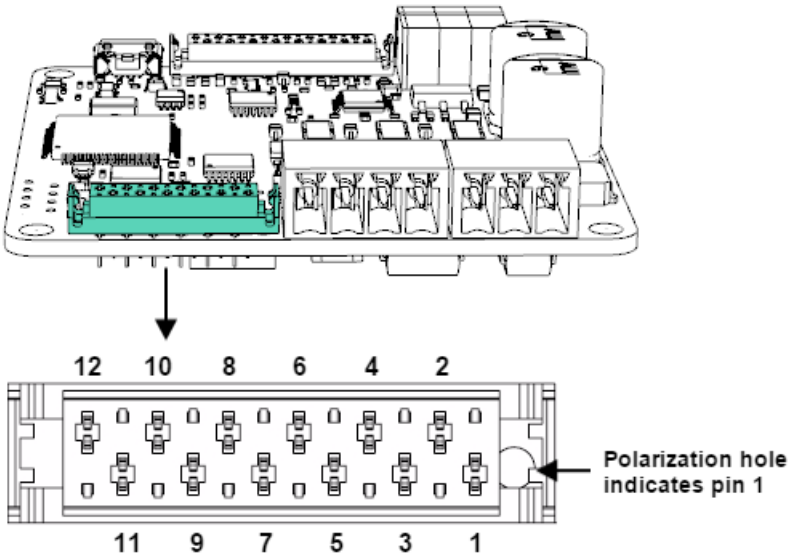
Crimped single cables makes wiring cleaner and is a preferred option for volume applications.

Mechanical fixation for non-connected pins

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

5.1.4 Feedback connector

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	HALL_1	Hall sensor input 1 (analog and digital)
11	HALL_2	Hall sensor input 2 (analog and digital)
12	HALL_3	Hall sensor input 3 (analog and digital)

Notes

- Polarization hole on PCB indicates pin 1 and ensures correct cable position.
- See Feedback connections for further information about different feedbacks wiring.
- Pluto 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, Hydra, Nix and Neptune servo drives, which allows using the IO starter kit and Pluto Cable Kit.

Previous versions compatibility

Feedback connector has changed from previous hardware revisions. Please see Hardware revisions for more information.

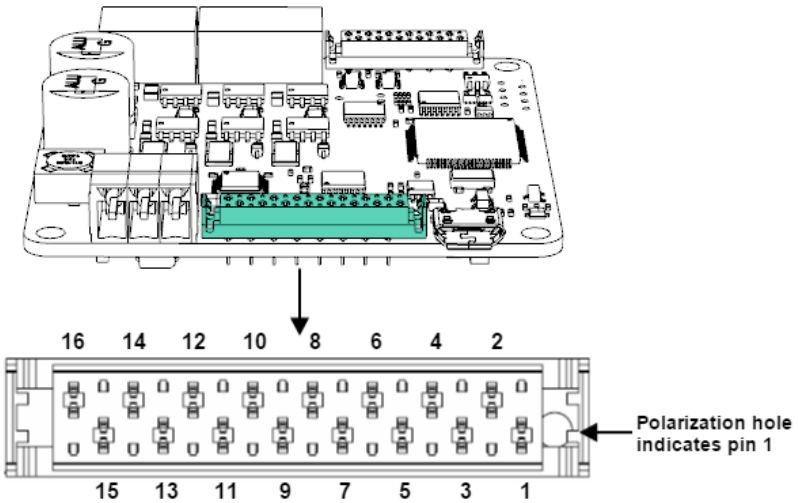
Ribbon cable mating	
Description	TE Micro-Match Male-on-Wire 1.27 mm pitch 12 position
Part number	TE Conectivity 8-215083-2
Distributor codes	Farnell 149093 Digi-Key A99460CT-ND Mouser 571-8-215083-2
Cable	
Part number	3M 3302/16 300SF
Distributor codes	Farnell 1369751 Digi-Key MC16M-300-ND Mouser 517-C3302/16SF

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 mm^2 (20 ~24 AWG) flexible wires.	

5.1.5 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. 5 V TTL level. Tolerant to 24 V inputs. (This input could be configured on-demand as hardware torque off input)
15	GPI1	General purpose single ended digital input 1. 5 V TTL level. Tolerant to 24 V inputs.
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.
- Pluto 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, Hydra, 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.

Previous versions compatibility

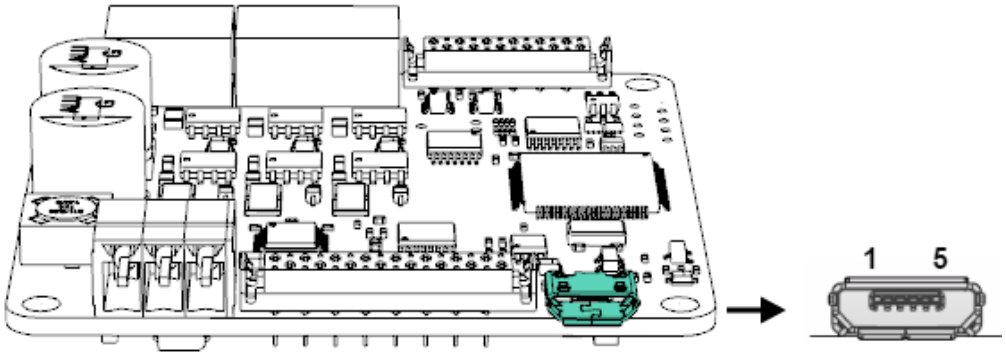
Note: In previous Pluto versions (1.0.1R), which had CLIK-Mate connectors, pin 16 was connected to GND. Please see Hardware revisions for more information.

Multi-core crimped cable mating	
Description	TE Micro-Match housing connector 1.27 mm pitch 16 position
Part number	TE Connectivity 1-338095-6

Distributor codes	Digi-Key A99495-ND Mouser 571-1-338095-6
Cable	
Use 0.2 ~ 0.5 mm^2 (20 ~24 AWG) flexible wires.	

5.1.6 USB connector

P5 Connector



5 pin horizontal micro-USB connector Amphenol FCI 10118193

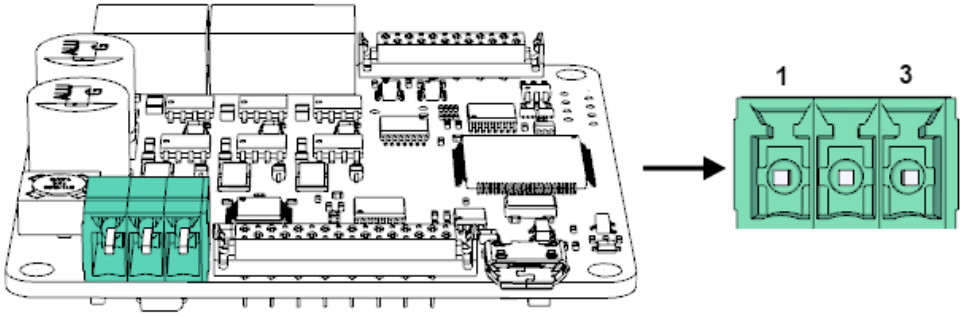
Pin	Signal	Function
1	USB_SUPPLY	USB +5 V supply input. Note, from version 3.0 onwards the drive logic can be powered from USB.
2	USB_D-	USB Data- line
3	USB_D+	USB Data+ line
4	NC	Not connected
5	GND	Ground
SHIELD	NC	Connector metallic shield, NOT CONNECTED.
Notes		

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

5.1.7 CAN connector

P6 Connector



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

Pin	Signal	Function
1	CAN_GND	CAN ground Connected to circuit ground on the non-isolated versions 1.x.x and 2.x.x. Isolated from circuit ground from versions 3.0 onwards.
2	CAN_L	CAN bus line dominant low
3	CAN_H	CAN bus line dominant high

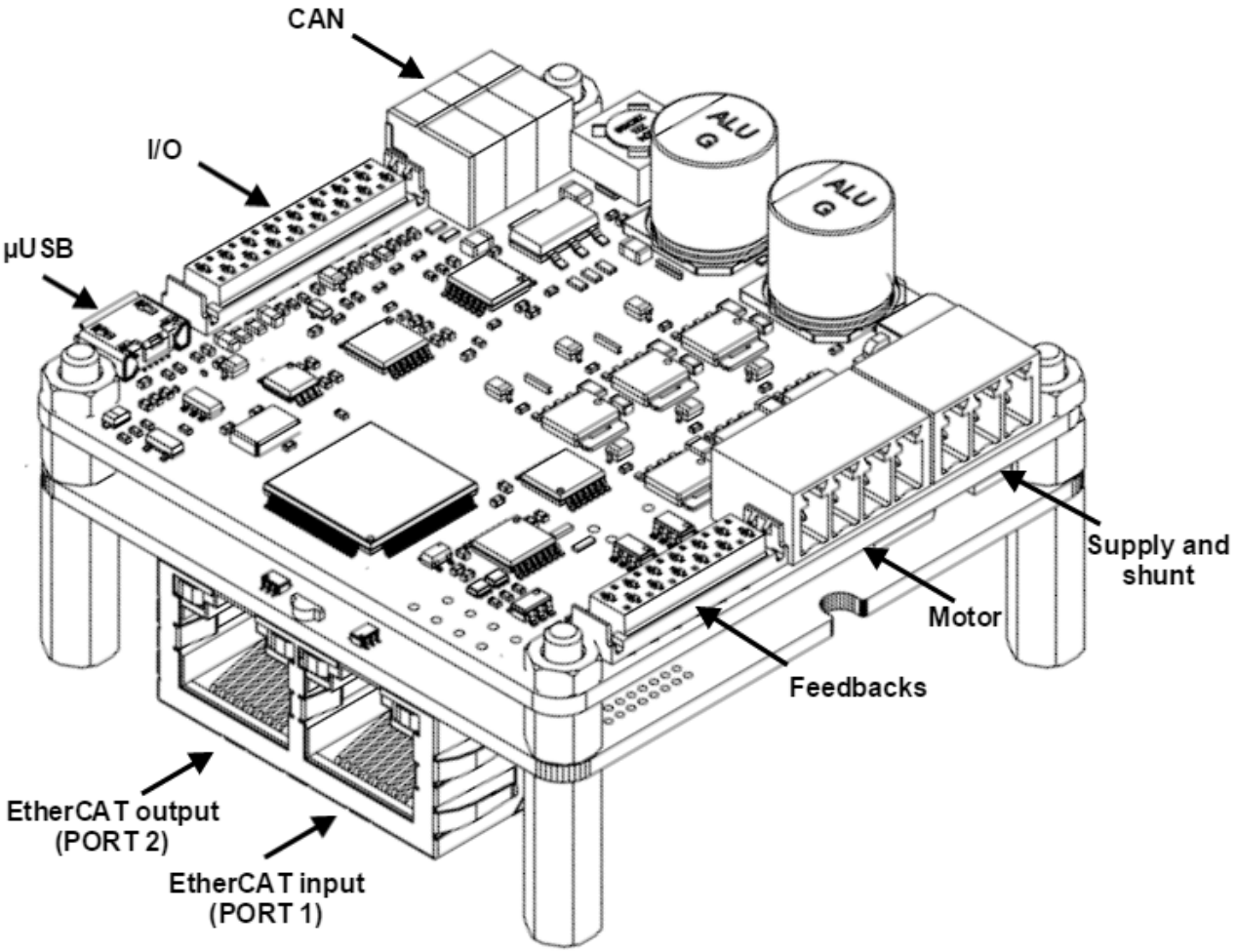
Notes	
From hardware revision 3.0 onwards, the CAN interface is isolated (1500 VDC),	
Mating	
Description	Pluggable terminal block, 3 positions 3.5 mm pitch
Part number	FCI 20020004-C031B01LF
Distributor codes	Mouser: 649-220004-C031B01LF
Notes	

- A 120 Ω termination is needed at the end of the CAN bus.
- See Communications for further information about CAN wiring.

Do not confuse with Supply connector

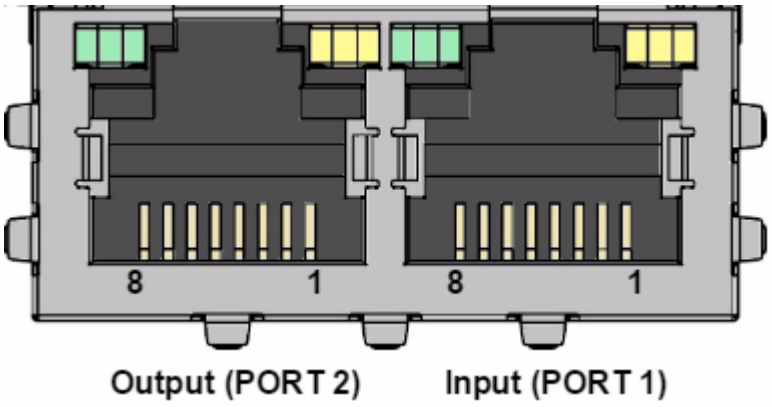
Please note that both CAN and Supply use the same type of connector, except for a difference of color: Supply and shunt connector is black and CAN connector is green. Please check you are connecting your power supply to the right connector.

5.2 Connectors position and pinout of Pluto with EtherCAT (PLU-x/xx-E)



5.2.1 EtherCAT connectors

P7-P8 Connectors



Dual RJ45 connector Magjack Wurth 7499021125

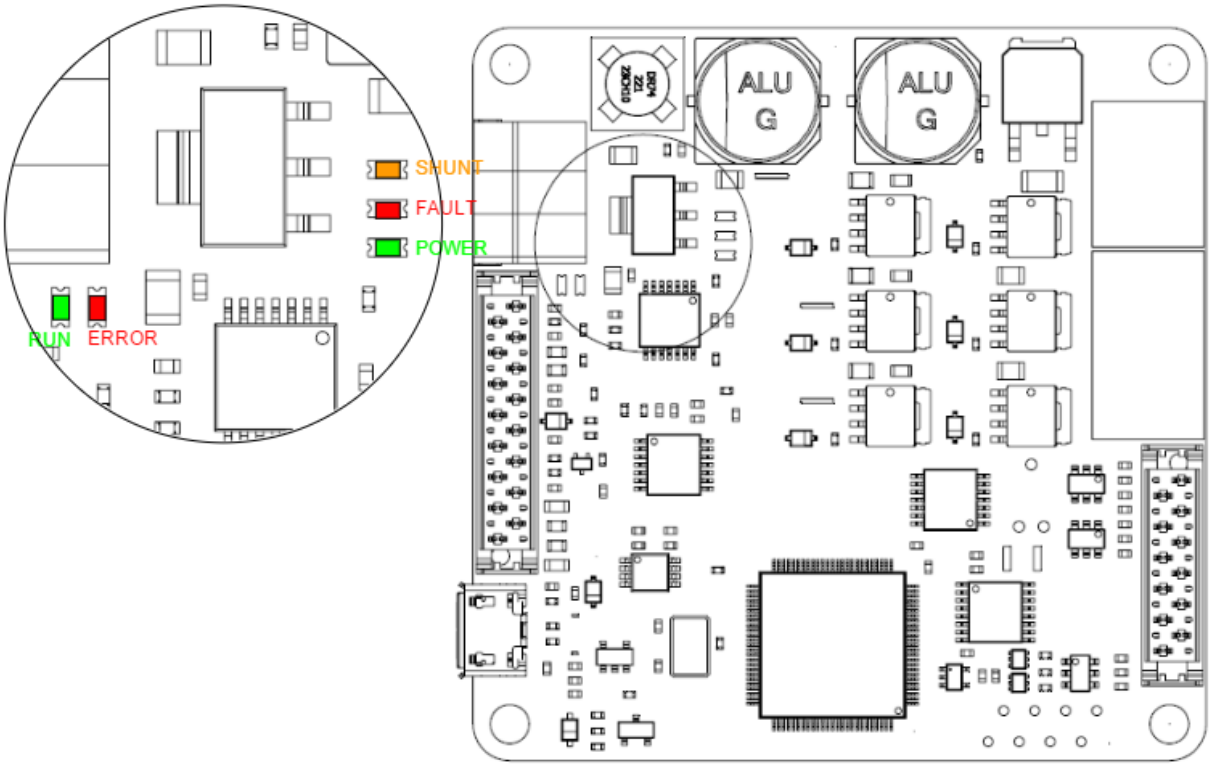
Pin	Signal	Function
1	TX_D+	Transmit Data+ line
2	TX_D-	Transmit Data- line
3	RX_D+	Receive Data+ line
4	+2V5	2.5 V generated internally
5	+2V5	2.5 V generated internally
6	RX_D-	Receive Data- line
7	NC	Not connected
8	GND_CHASSIS	Connected to the connector chassis
Notes		
• Pinout is the same for Input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

6 Signalling LEDs

Pluto Servo Drive provides information through 5 signalling LEDs:

- Supply and operation: 3 LEDs next to the electrolytic capacitors.
- CANopen communication: 2 LEDs next to the CAN connector.

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



6.1 Power and operation signalling LEDs

Three LEDs situated next to the electrolytic capacitors 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.

6.2 CAN signalling LEDs

Two LEDs besides the CAN connector 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:

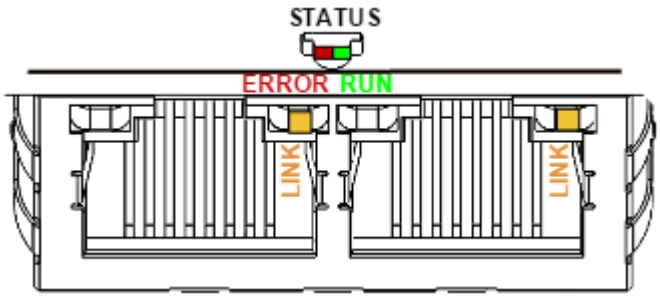
*** Possible LED states**	**Description**
ON	The LED is always on

* Possible LED states	Description
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%.

6.3 EtherCAT signalling LEDs

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



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

RUN LED state	**EtherCAT slave status**		**ERROR LED** state	**EtherCAT slave status**
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

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

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

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

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

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

7 Wiring and Connections

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

7.1 Protective earth

Connection of Pluto 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. This document provides further information on EMC in servo drives Electromagnetic Interference Issues With Servo Drive Systems.

Reducing EMI susceptibility

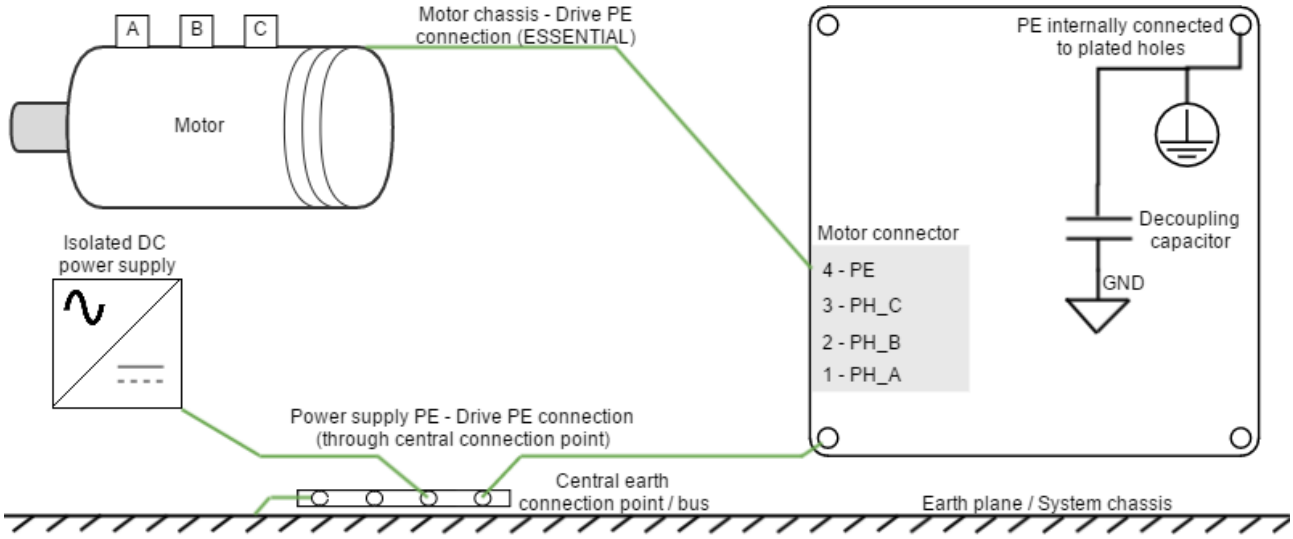
Connecting the drive PE terminals and cold plate screws **to your system Earth and to the motor housing solves many noise and EMI problems.** The PE drive terminals are decoupled to power ground through a safety capacitor. This provides a low impedance preferential path for coupled common mode noises 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.

Pluto Servo Drive PE 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.

1. test
2. test2

A diagram of the recommended Earth wiring is shown following.



Earth plane reference

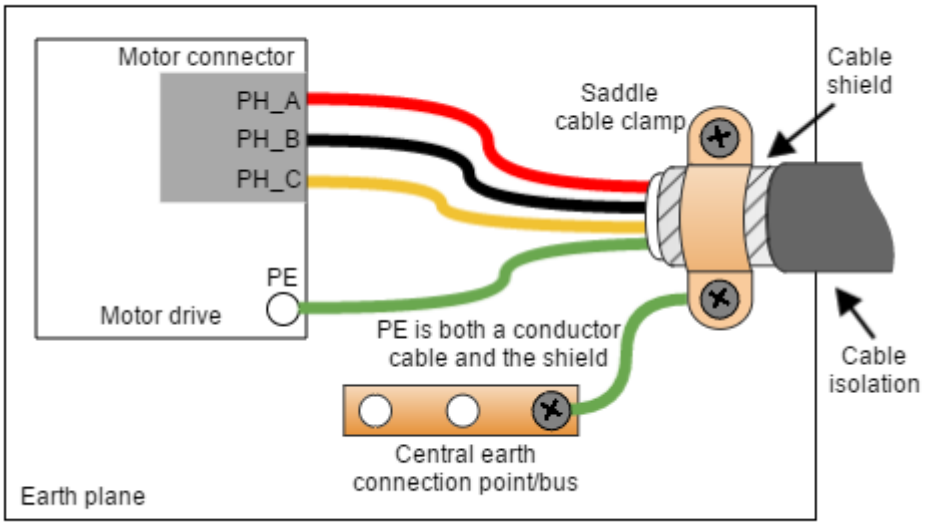
While some systems will not have a "real Earth" connection, use your **machine chassis**, the metallic structure of the device or a good grounding conductive plane as your reference earth.

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 Pluto Servo Drive standoffs.
- For achieving low impedance connections, use wires that are **short, thick, multistrand cables** or preferably **conductive planes**. PE wire section should be, at least, the same as power supply cables. Always **minimize PE connection length**.

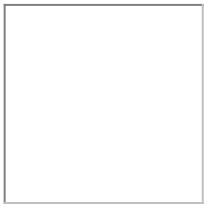
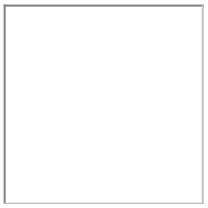
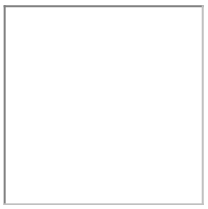
For an even better EMI immunity, **use shielded or armored cables** with isolating jacket, connecting the shield to PE with a cable clamp.



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

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

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

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

7.2 Power supply

The Pluto Servo Drive is supplied from the Supply and shunt connector, using the same terminal for logic and power supply (10 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.

Power supply for configuration

Power supply has to be provided for configuration purposes. Pluto Servo Drive can not be supplied from USB connector.

Disconnection recommendations

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

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

7.2.1 Power supply requirements

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

- The **voltage** should be the targeted for the motor. This means up to **48 V** for all the Pluto versions. 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 **2 A** for the **PLU-1/48,** up to **10 A** for the **PLU-5/48** and up to **16 A** for the **PLU-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
CUI Inc.	VBM-100-48	48	2.1		Switching closed frame power supply recommended for Pluto-1/48, 100 W
TDK Lambda	PFE500F48	48	10.5		Switching closed frame power supply recommended for Pluto-5/48, 500 W
TDK Lambda	PFE1000F48	48	21		Switching closed frame power supply recommended for Pluto-8/48, 1000 W

7.2.1.1 Inrush current

During power up a short duration high current peak is needed to charge the drive internal DC bus capacitors (see specification page to know the value of the capacitors), this is called inrush current. This current will only be limited by the power supply, the wiring and connectors resistance, the drive reverse polarity protection resistance (~ 65 mΩ) and the bus capacitance equivalent series resistance (ESR ~ 5 mΩ).

Since power supplies have a power-up ramp (or soft start) this typically does not represent a problem at all. However in systems with many axis in parallel or when the DC supply is controlled by a relay, an inrush current limit circuit is strongly suggested, otherwise, the peak can cause unnecessary stress to the power supply and electronics that could reduce its lifespan. There are 2 common ways to solve this.

- Use a passive Inrush Current Limiter (**ICL**). Which is a negative temperature coefficient (NTC) resistor showing a high resistance at startup that limits the peak and then drops down during operation. This option provides the lowest cost and simplicity but will become hot during operation and reduce system energy efficiency. Choose according to your system current ratings and power supply capacity.
- Use an active precharge relay circuit. By having a current limit resistor between power supply that will limit the inrush and then bypass it with a electromechanical or solid state relay. Some relays include an on-delay function. An alternative is to activate the relay from the driver after power up, by using a macro and a GPO to control the relay.

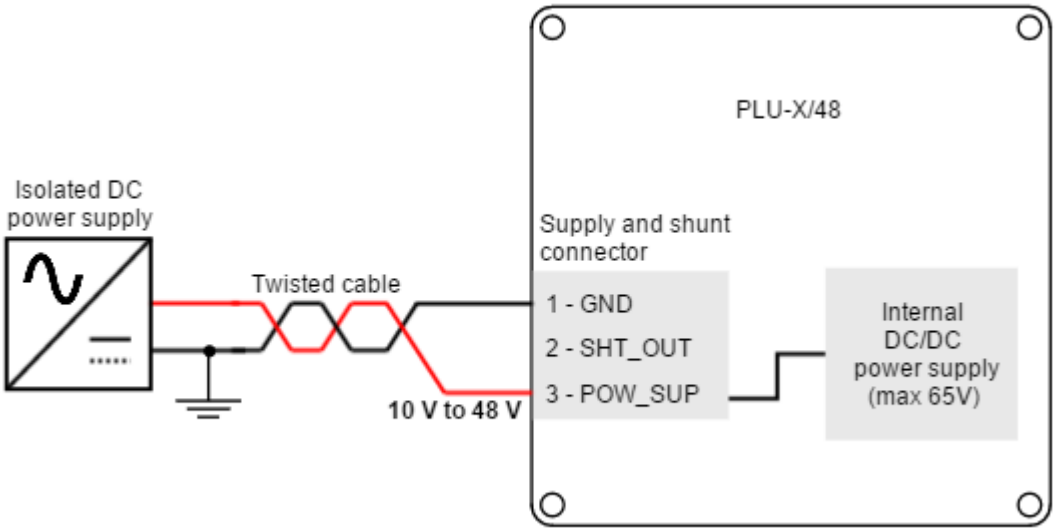
7.2.2 Power supply connection

Pluto logic and power supply are provided through the same terminal. All Pluto versions support an input voltage of +10 V to +48 V.

Twisted cables

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

The following picture show the Pluto supply wiring diagram.

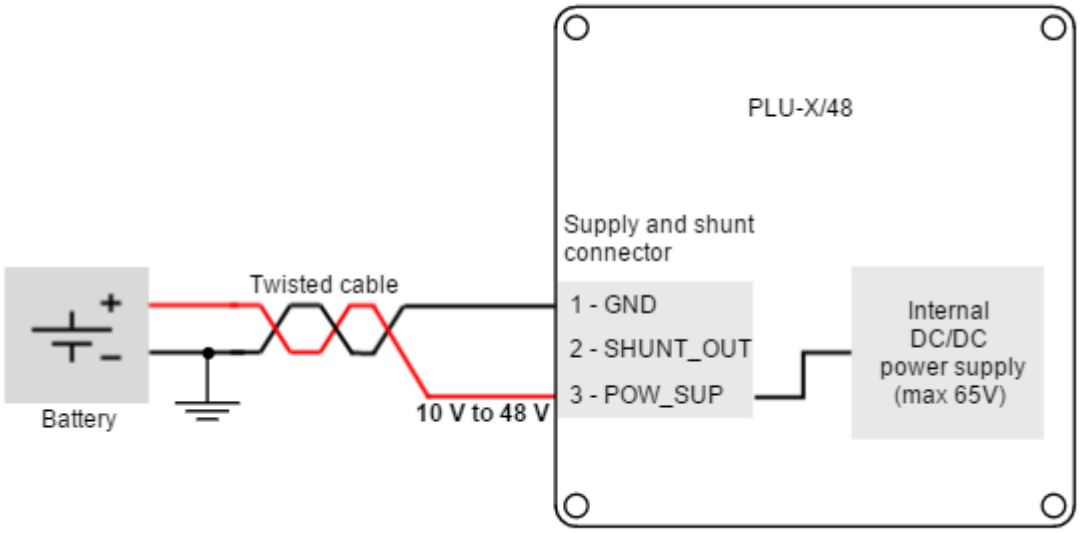


Isolated power supplies

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

7.2.3 Battery supply connection

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

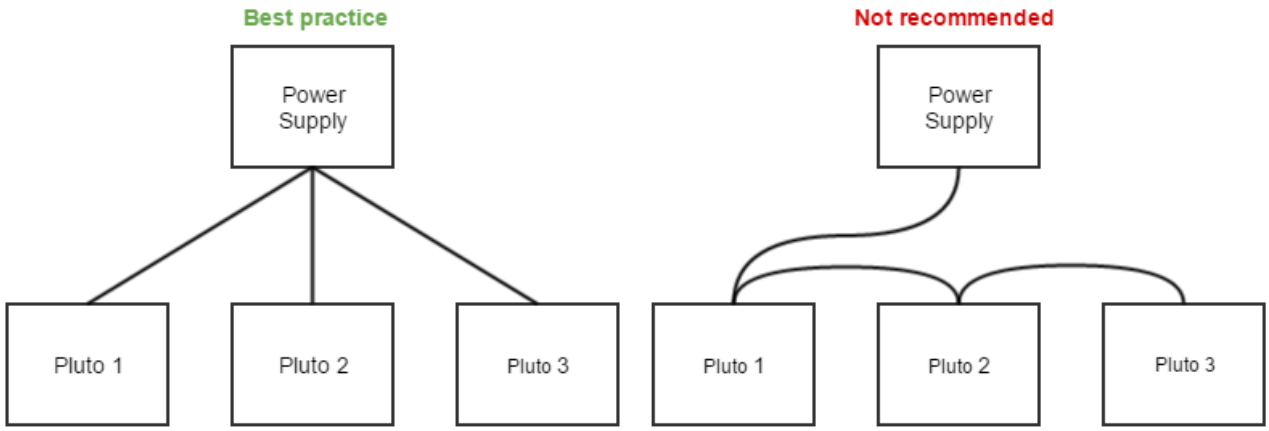


Motor braking current

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 Pluto current ratings.

7.2.4 Connection of multiple drives with the same power supply

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



7.2.5 Power supply wiring recommendations

7.2.5.1 Wire section

The minimum wire section is determined by the current consumption and the allowed voltage drop across the conductor. It is preferred to use **wide section stranded wires** to reduce impedance, power losses and ease the assembly. Insulator size should not exceed 3.5 mm (connector pitch). Following table indicates recommended section for the Pluto 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)

7.2.5.2 Wire ferrules

For **low power applications**, it is recommended to use wire ferrules to prevent cable damage or wrong contacts. For **higher power applications, direct cable connection is recommended**, since it provides lower contact resistance. Due to the connector's size, the maximum allowed ferrule size is 0.5 mm^2. Ensure the insulator does not exceed 3.5 mm (connector pitch). Following table indicates recommended wire ferrules for the Pluto 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)

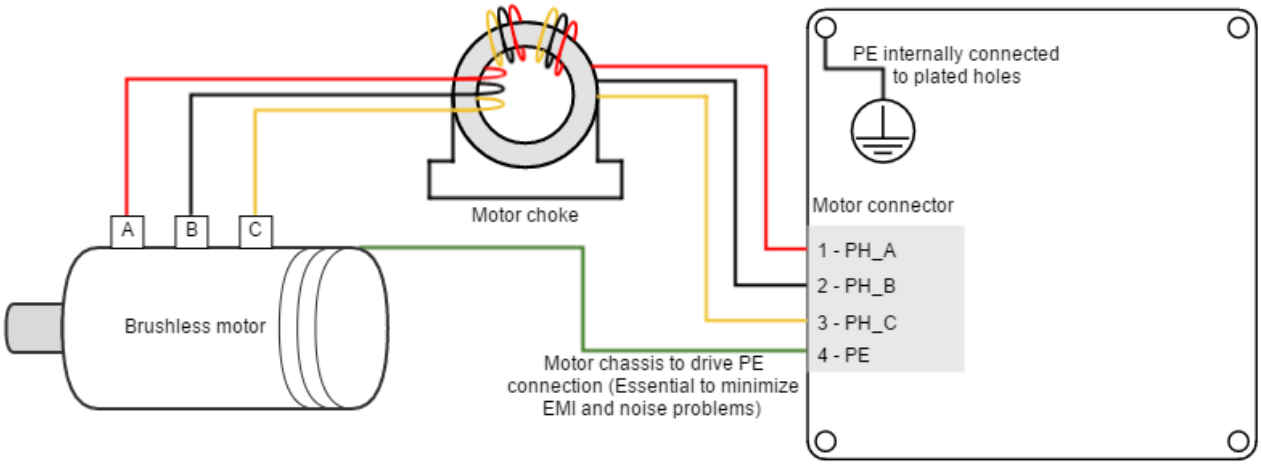
7.2.5.3 Wire length

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

7.3 Motor and shunt braking resistor

7.3.1 AC and DC brushless motors

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



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

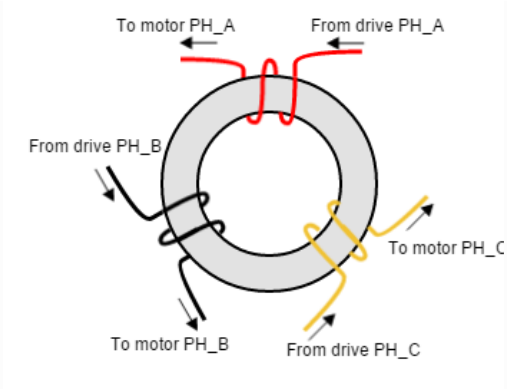
Common-mode choke

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

Proper three-phase motor choke wiring

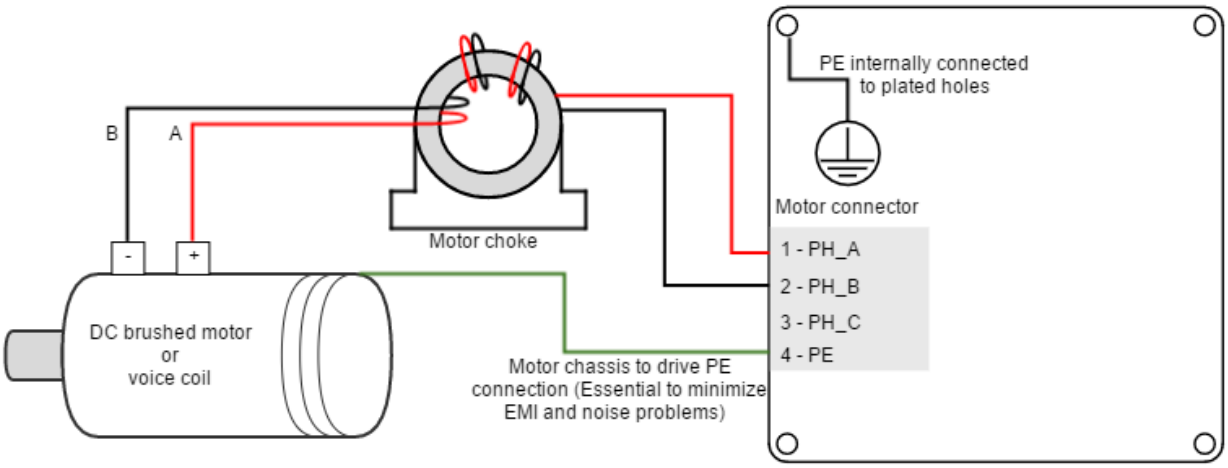
In order to minimize the capacitive coupling of the motor wires, and therefore cancelling the effect of the common mode rejection effect, the choke has to be properly wired.

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



7.3.2 DC motors and voice coils actuators

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



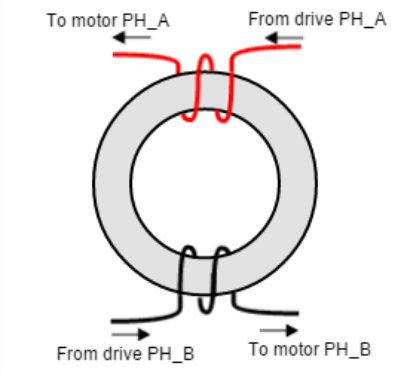
Common-mode choke

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

Proper DC motor choke wiring

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

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



7.3.3 Motor wiring recommendations

7.3.3.1 Wire section

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

7.3.3.2 Wire ferrules

For **low power applications**, it is recommended to use wire ferrules to prevent cable damage or wrong contacts. For **higher power applications, direct cable connection is recommended**, since it provides lower contact resistance. Due to the connector's size, the maximum allowed ferrule size is 0.5 mm^2. Ensure the insulator does not exceed 3.5 mm (connector pitch). Following table indicates recommended wire ferrules for the Pluto 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)

7.3.3.3 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. 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 Pluto Servo Drive specifications and has a great performance at low frequencies.

Type	Manufacturer	Reference
Low frequency ferrite	Laird Technologies	LFB360230-300

7.3.3.4 Wire length

- The distance between the Pluto 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 Pluto outputs and the cable. The inductors must be magnetically shielded, and must be rated for the motor surge current. Typical values are around 100 µH.

7.3.4 Shunt braking resistor

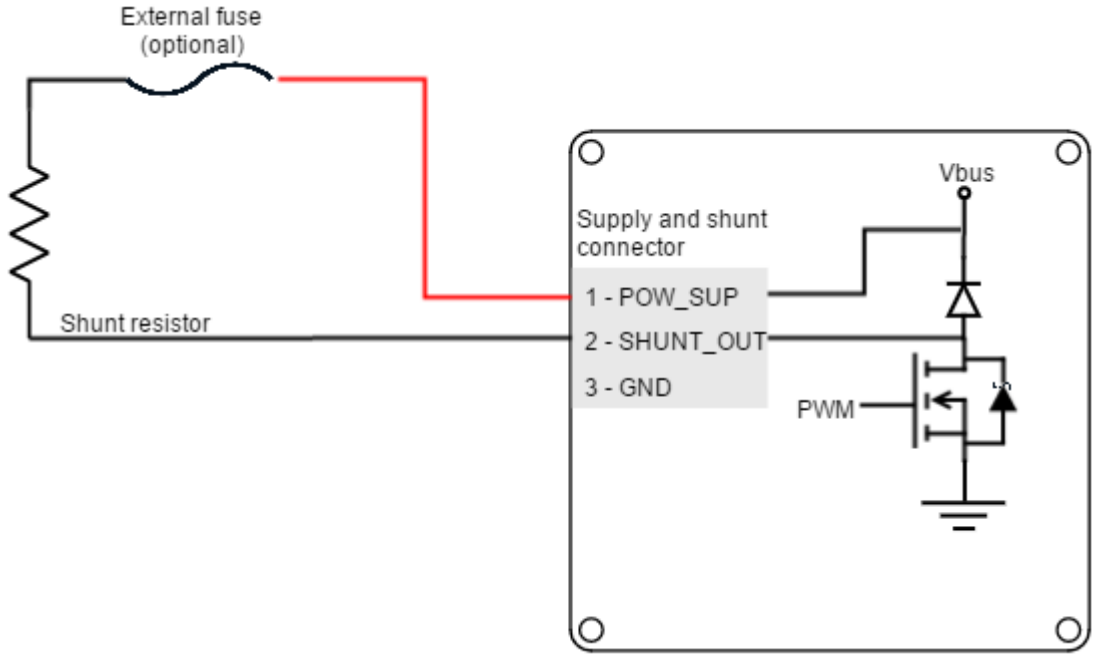
While decelerating a motor (abrupt motion brakes or reversals), the mechanical energy is converted into electrical energy by the motor. This energy is regenerated into the power supply and could lead to an increase of the supply voltage. To absorb this energy the Pluto **incorporates a shunt transistor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

7.4 Feedback connections

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

- Digital Halls
- Analog Halls
- Quad. Incremental encoder

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

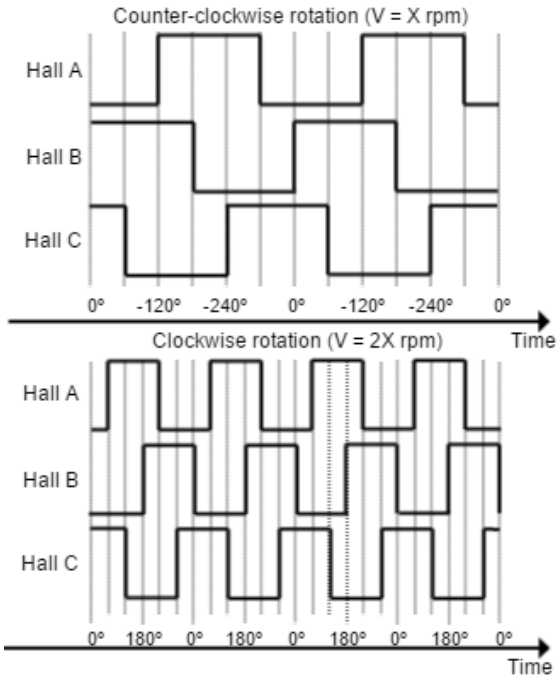
- PWM encoder
- Analog input for potentiometer
- Analog input for DC tachometer

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

7.4.1 Digital Halls interface

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

Digital halls signals example



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

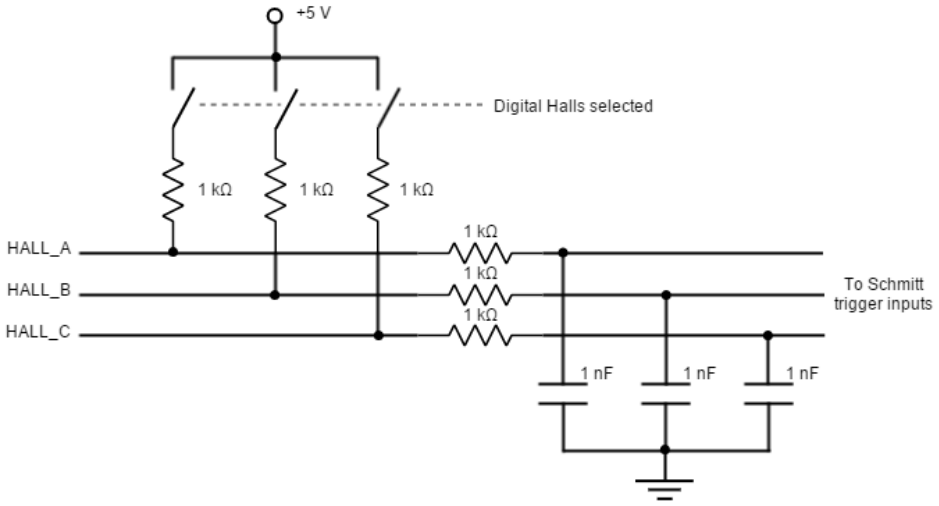
This interface accepts 0-5 V level input signals. Inputs are pulled up to 5 V, so industry standard open collector and logic output hall effect sensors can be connected. Next table summarizes digital halls inputs main features:

Specification	Value
Type of inputs	Non-isolated Single ended with pull-up and low pass filter ESD protected
Number of inputs	3
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact) IEC 61000-4-4 (EFT) 40 A (5/50 ns)
Voltage range	0 ~ 5 V
Maximum voltage range	-0.5 ~ 5.5 V
Maximum recommended working frequency	1 kHz
1st order filter cutting frequency (-3dB)	160 kHz
Sampling frequency	10 ksps
Type of sensors	Open collector Logic output Push-pull output
Pull-up resistor value	1 kΩ (The pull-up is activated only when the drive is configured to use digital hall sensors)

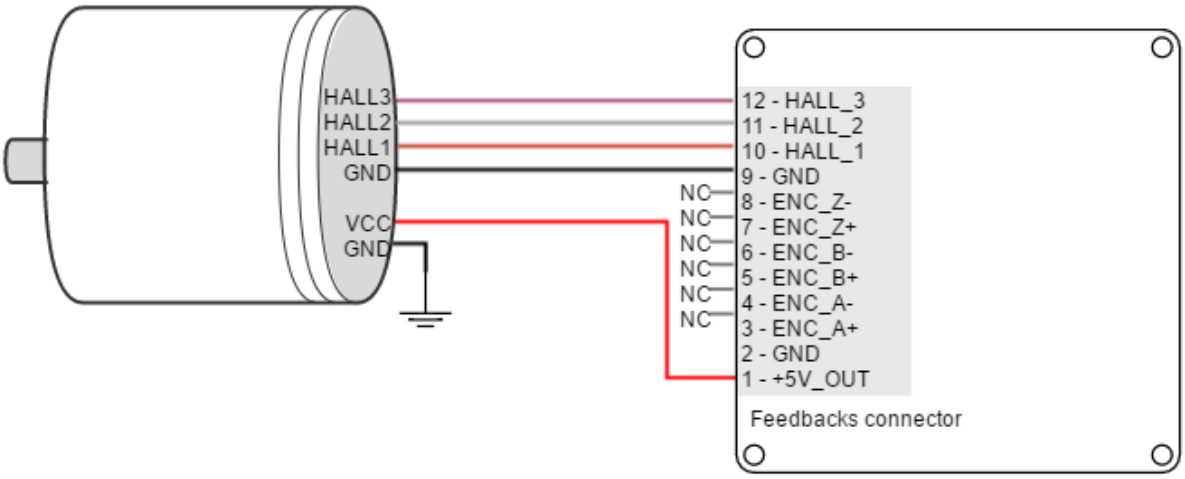
Digital and analog Halls

Digital halls input pins are shared with Analog Halls interface pins.
The 1 kΩ pull-up resistors are disconnected when Analog-halls input is selected to prevent analog data corruption.

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



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



Velocity control with Halls

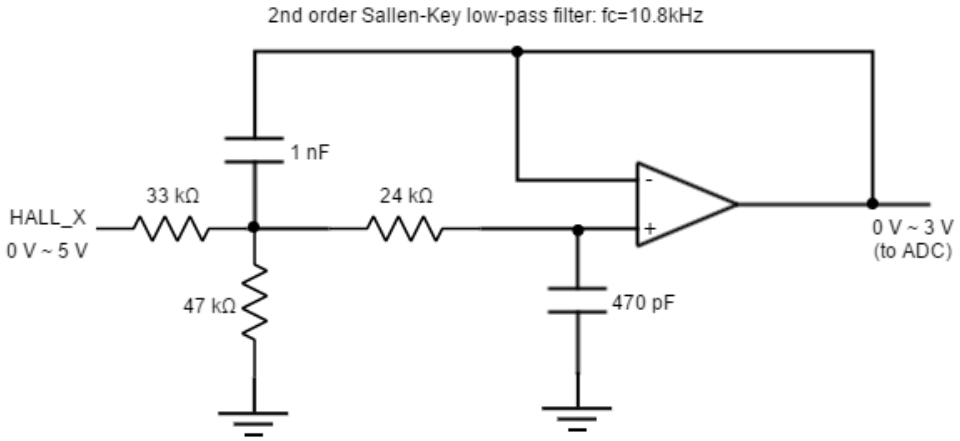
Due to inherent low resolution of motor mounted Hall sensors, they are not recommended for velocity feedback in low speed applications.

7.4.2 Analog Halls interface

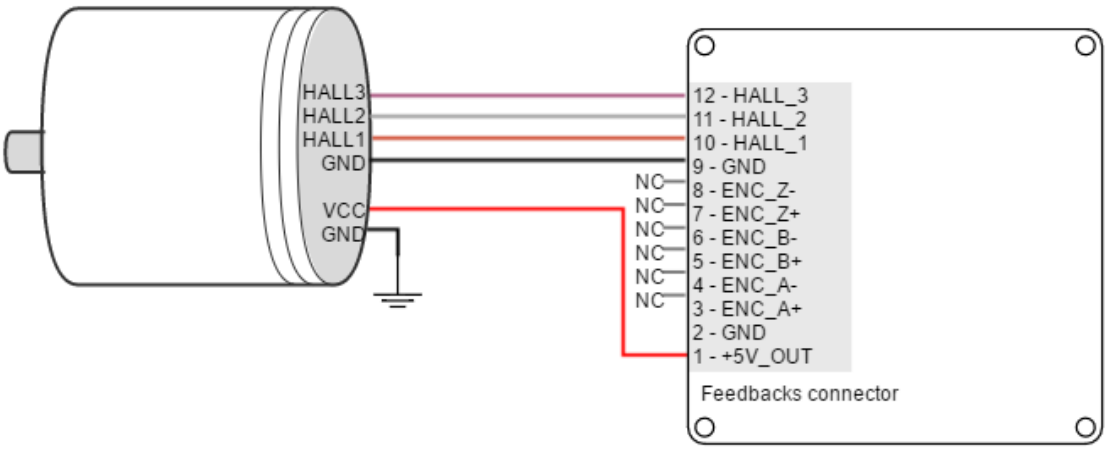
The Pluto Servo Drive can operate with analog Hall sensors (also known as linear halls) as feedback option. Signals provided by these sensors are typically 5 V peak-to-peak sinusoidal signals, with 2.5 V offset and a phase shift of 120 degrees. These sensors can be used for a fine positioning of the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

Specification	Value
Type of inputs	Non-isolated Single ended analog filtered ESD protected
Number of inputs	3
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact) IEC 61000-4-4 (EFT) 40 A (5/50 ns)
Maximum recommended working frequency	1 kHz
2nd order filter cutting frequency	10.8 kHz
Sampling frequency	10 ksps
Voltage range	0 ~ 5 V (10 bits)
Maximum voltage range	-0.3 ~ 5.3 V
Input impedance	> 24 kΩ

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



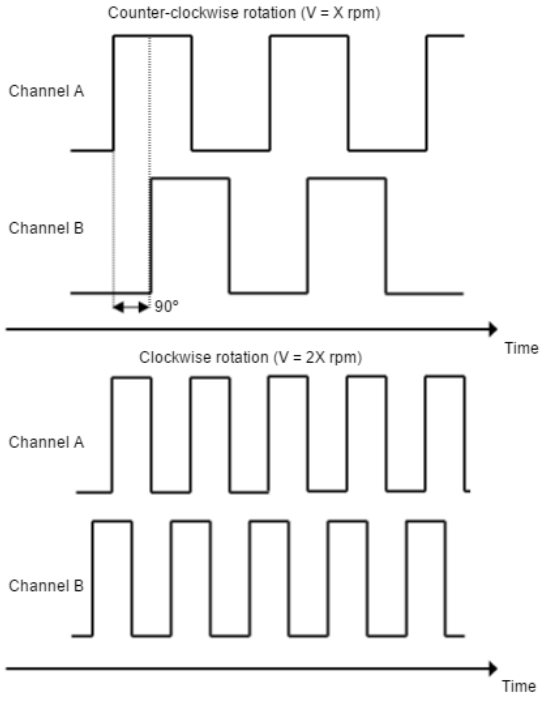
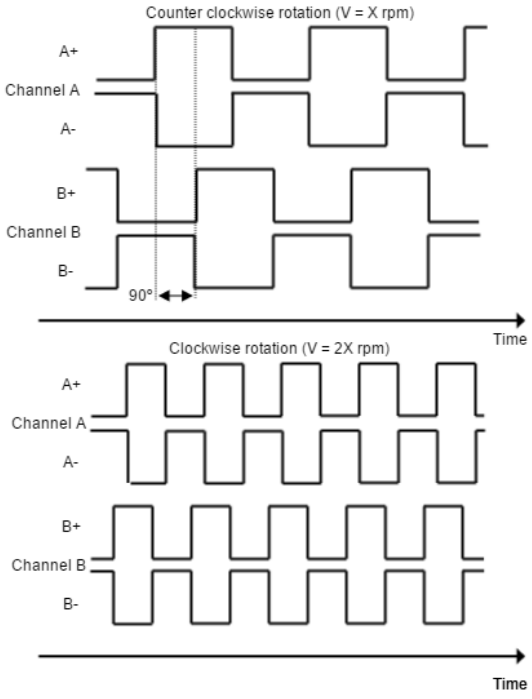
Next figure shows how to connect the linear Halls to the Pluto Servo Drive. Refer to Feedback wiring recommendations for more information about connections and wires.



7.4.3 Digital Incremental Encoder

Pluto 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 Pluto 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.

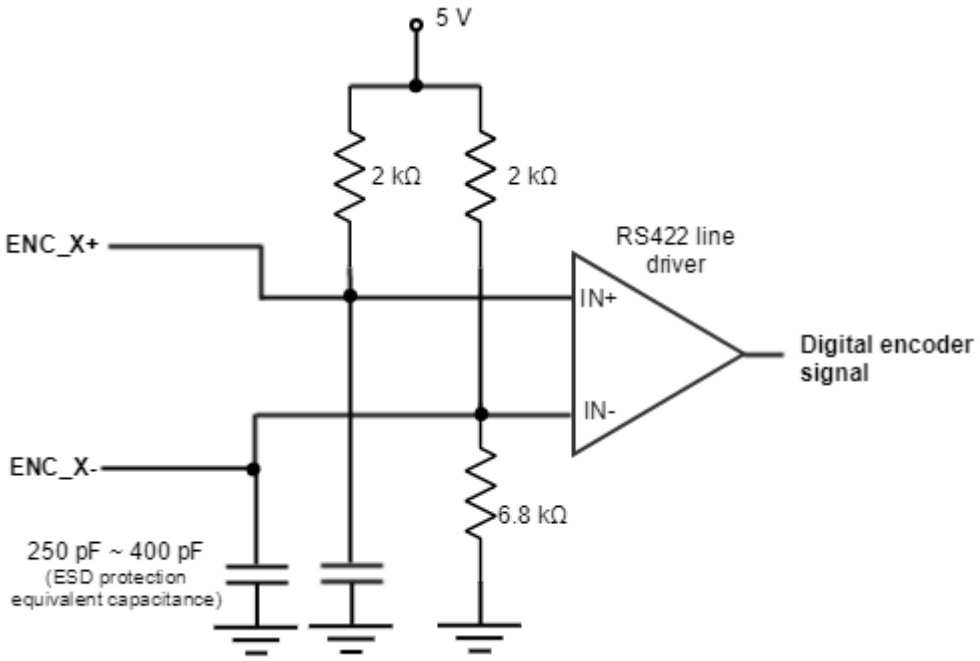
The Pluto Servo Drive has one differential digital encoder interface, with optional index signal input. Index signal (Z) is a single pulse per revolution signal that can be used to know absolute positions. Next table illustrates digital encoder inputs main features.

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) 2 kΩ to 5 V ENC_x- (negative input) 1.5 kΩ to 4 V (equivalent)

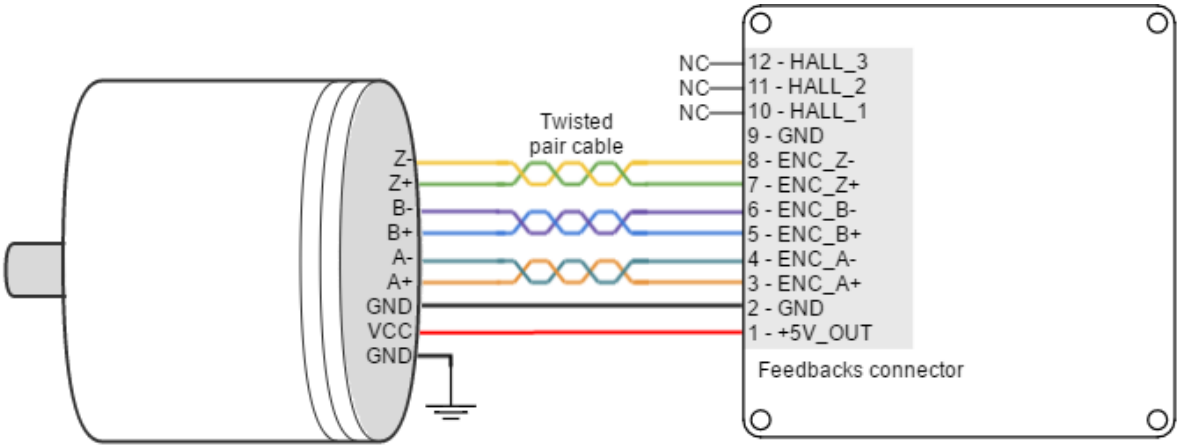
For encoder signal reception, an RS-422 differential line receiver is used. The high signals (ENC_A+, ENC_B+ and ENC_Z+) are pulled up to +5 V, and the low signals (ENC_A-, ENC_B- and ENC_Z-) are biased to 4 V (approx). This arrangement let the user to connect either differential output encoders or single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

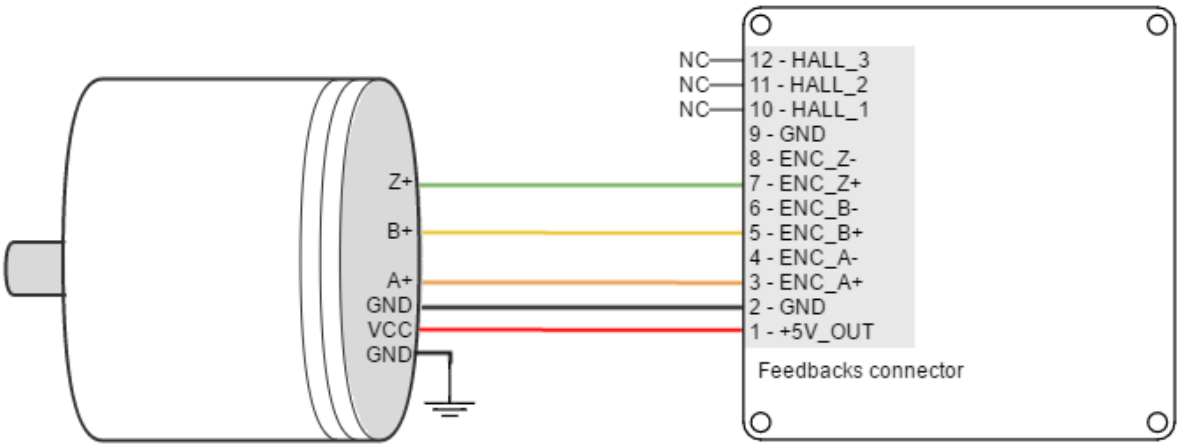
The encoder interface also accepts an RS-422 differential quadrature line drive signal in the range of 0 V to 5 V, up to 10 MHz. When single ended encoder is connected, only high signals (ENC_A+, ENC_B+ and ENC_Z+) must be used.

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



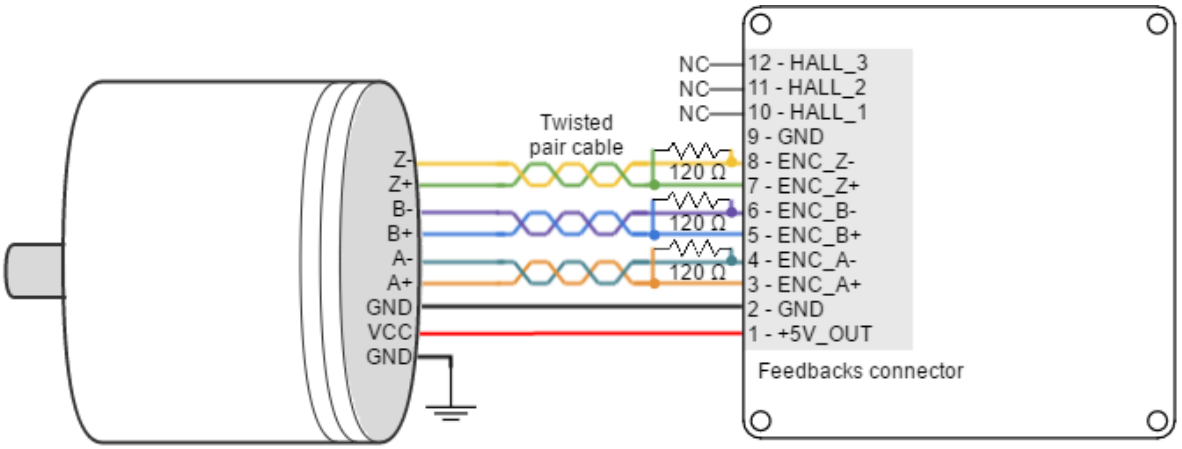
Next figures illustrate how to connect a differential and a single ended encoder to the Pluto Servo Drive. Refer to Feedback wiring recommendations for more information about connections and wires.



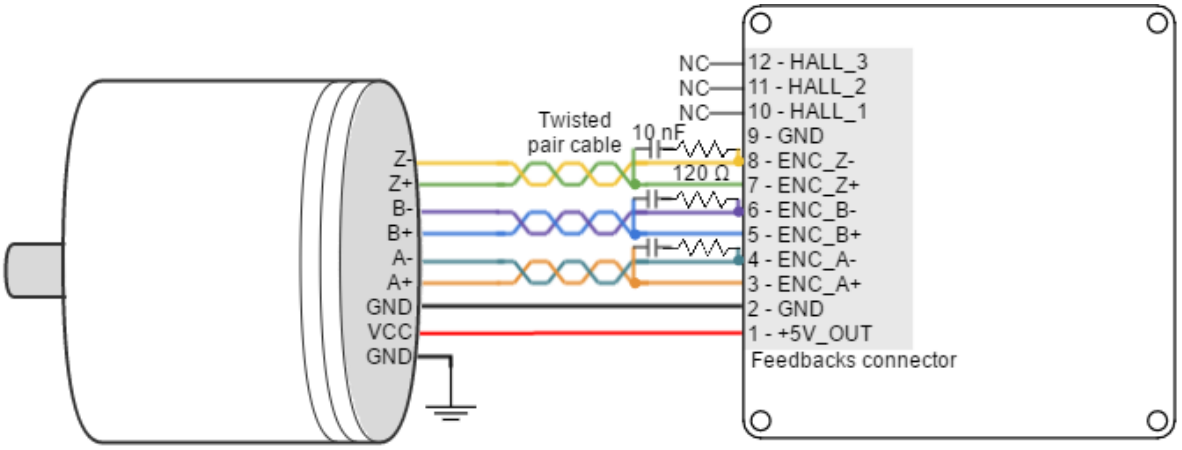


7.4.3.1 Termination resistors

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



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



Suggested part numbers:

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

7.4.3.2 Digital encoders with single ended 24 V or 10 V outputs

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

For 24 V single ended It is recommended to use a 4.7 kΩ 1/4 W resistor in series with the ENC_X- (inverting) inputs and leave the ENC_X+ floating. For 10 V use the same connection but with 2.2 kΩ 1/10 W resistor in series with ENC_X- inputs.

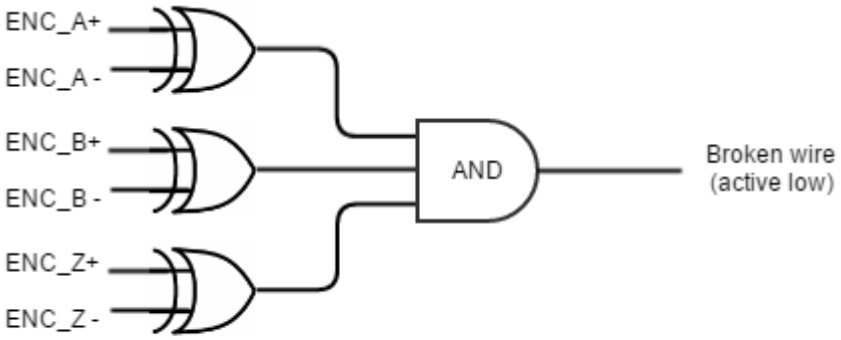
7.4.3.3 Digital encoders with differential 24 V or 10 V outputs

To interface with 24 V or 10 V push-pull style differential encoders, it is recommended to connect resistors in series between the encoder signals and the corresponding drive inputs. For 24 V encoders use 4.7 kΩ 1/4 W. For 10 V encoders use 2.2 kΩ 1/10 W.

This ensures a correct differential signal reading as well as limiting currents to safe levels. Note that this additional resistance may limit the maximum encoder frequency to approximately 1 MHz by making a low pass filter with the input capacitance.

7.4.3.4 Encoder broken wire detection

Pluto 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.

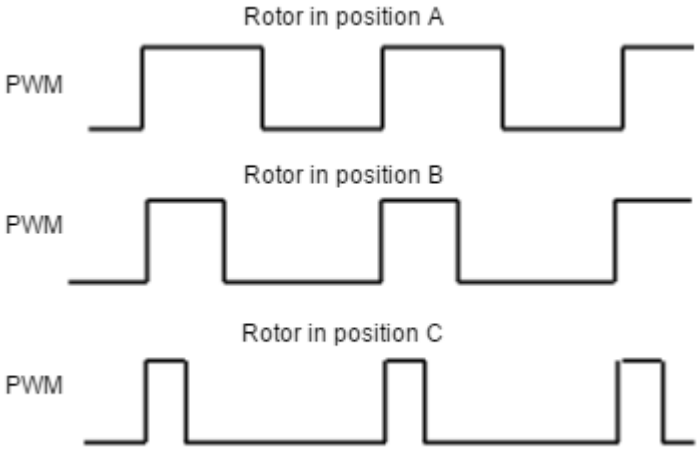
Encoder without Index (Z) line

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.

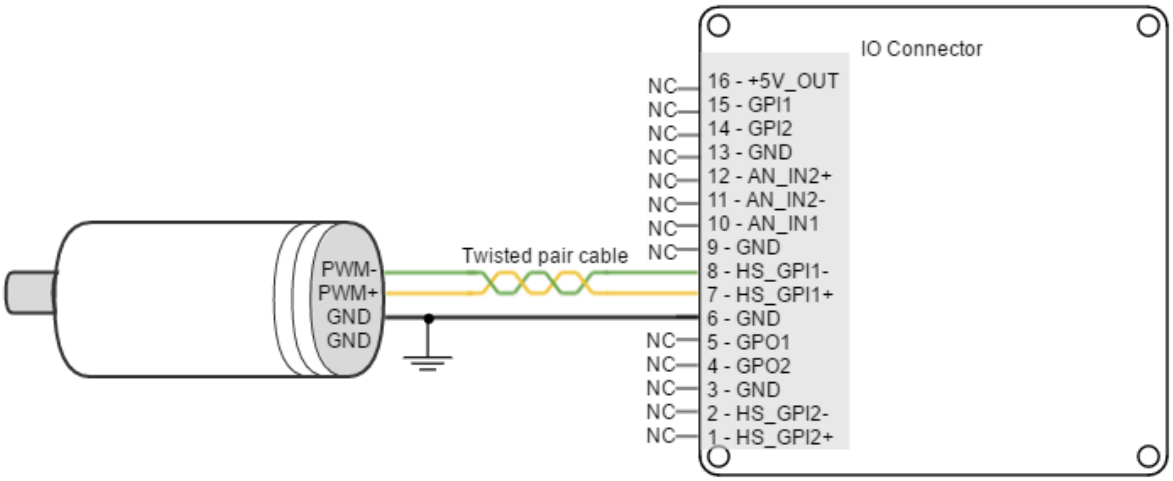
7.4.4 Digital input feedback - PWM encoder

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

Next figure illustrates PWM feedback input for different rotor positions:

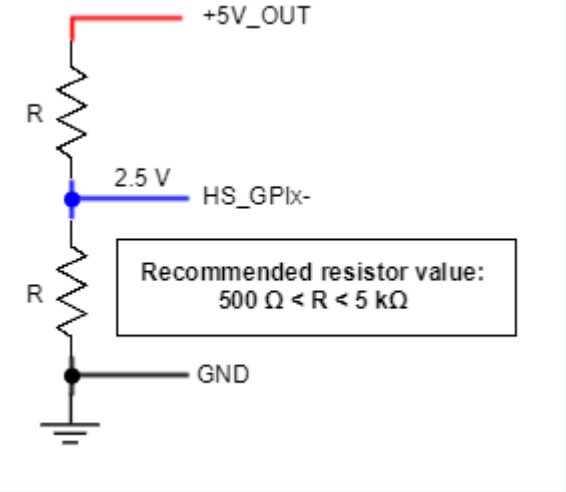


Next figure illustrates how to connect a differential PWM encoder to the Pluto Servo Drive:



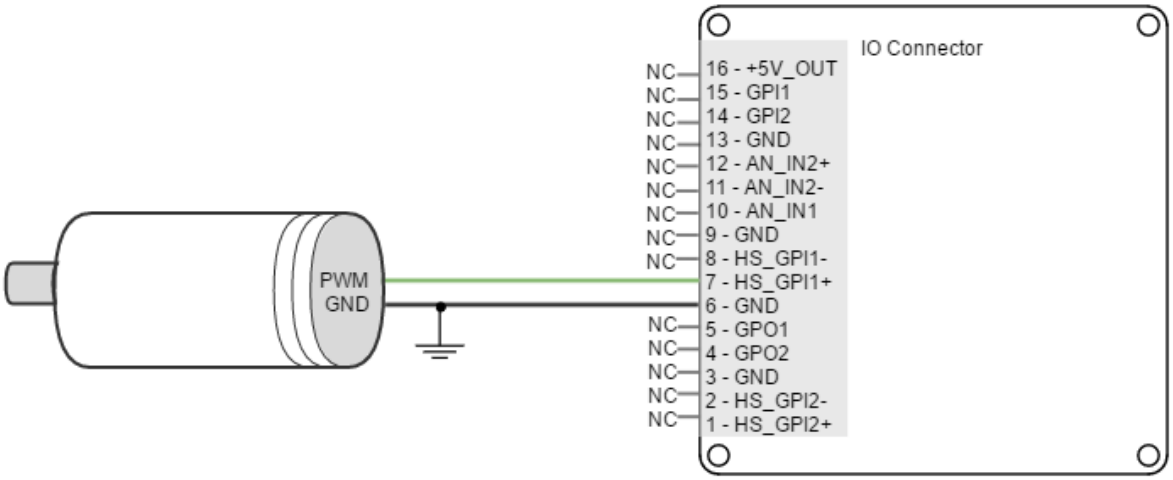
Single ended operation

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



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

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



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

7.4.5 Analog input feedback

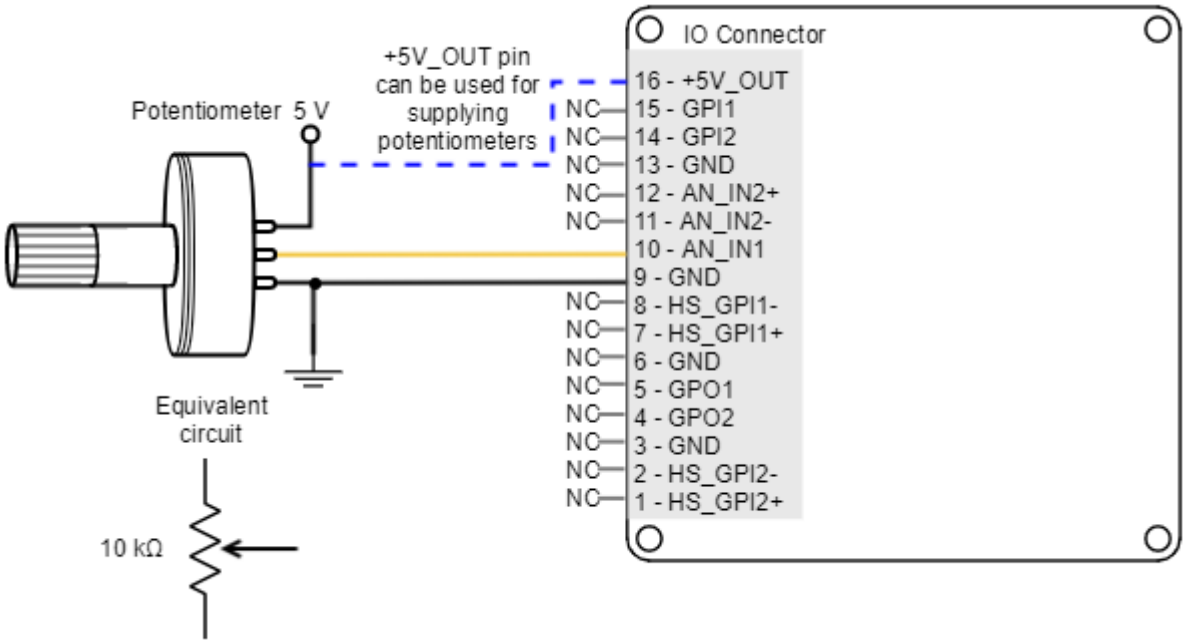
Pluto Servo Drive can also use analog feedback systems connected through the I/O connector. From the voltage level of one analog input, the position or velocity of the rotor can be calculated. The Pluto have 2 analog inputs that can be used for feedback input, each one with a different input range. The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

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

7.4.5.1 Potentiometer

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

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



Recommended potentiometer resistance

Potentiometers with high values of resistance (> 10 kΩ) can result in non linear behavior due to its the drive parallel input resistors. High resistance values also reduce the signal to noise ratio, making it easier to have disturbances and reducing the quality of the measure.
However, a very small value of resistance may also consume too much power and cause self heating (which causes additional variations on resistance).
Therefore, **use the smallest value of resistance** that:

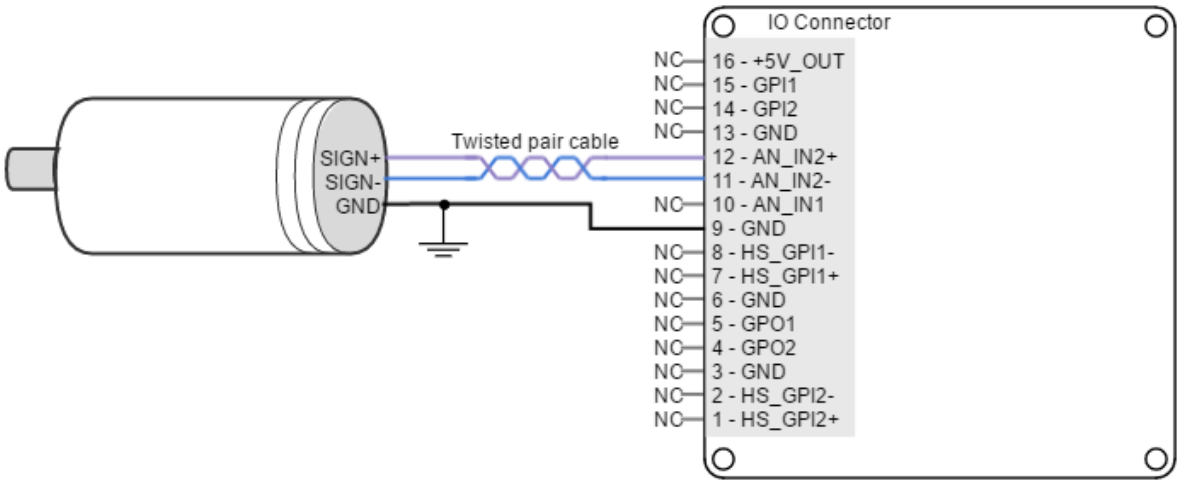
- Does not exceed 1/2 of the potentiometer power rating (to allow safety margin and prevent self heating).
- Does not exceed the +5V_OUT current capacity.

Typically 1 kΩ to 10 kΩ will be preferred.

7.4.5.2 DC tachometer

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

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



7.4.6 Feedback wiring recommendations

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

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

7.4.6.1 Recommendations for applications witch close feedback and motor lines

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

- Use a common mode choke on the motor phases. This single action can reduce common mode noise drastically and will solve most problems. See recommended wiring in Motor 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.

7.5 I/O connections

The Pluto 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, Pluto 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.

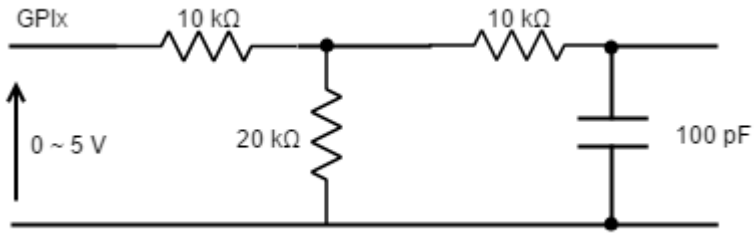
7.5.1 General purpose single ended digital inputs interface (GPI1, GPI2)

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

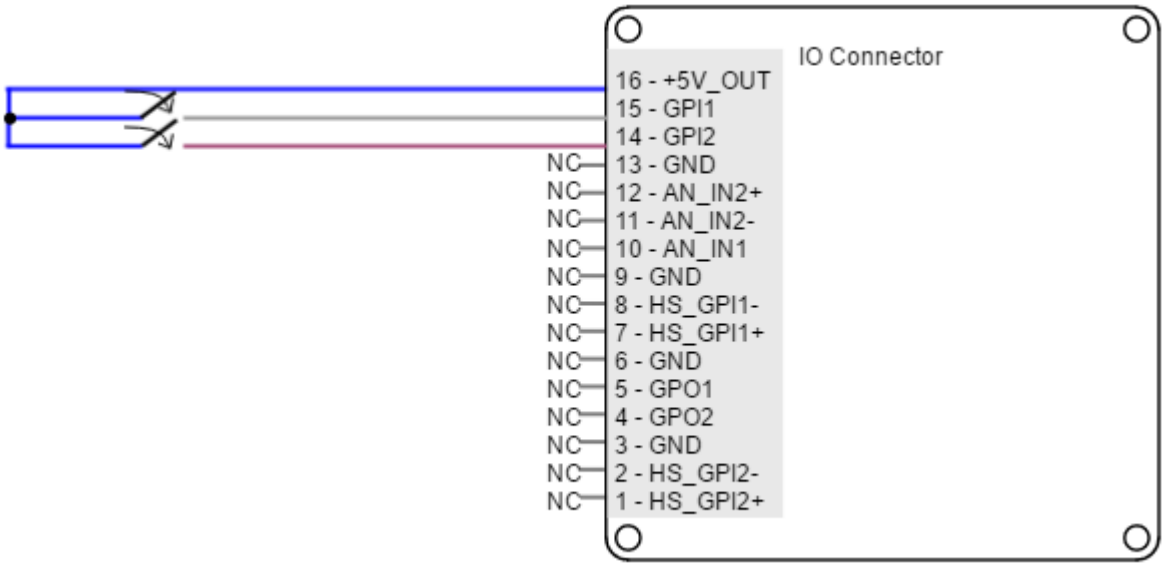
Specification	Value
Number of inputs	2 (GPI1, GPI2)
Type of input	Single ended ESD protected Low pass filtered
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Input current	0.7 mA @ 5 V; 2 mA @ 15 V
High level input voltage	4 V < Vin < 24 V
Low level input voltage	0 < Vin < 1 V
Input impedance	30 kΩ

Specification	Value
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:



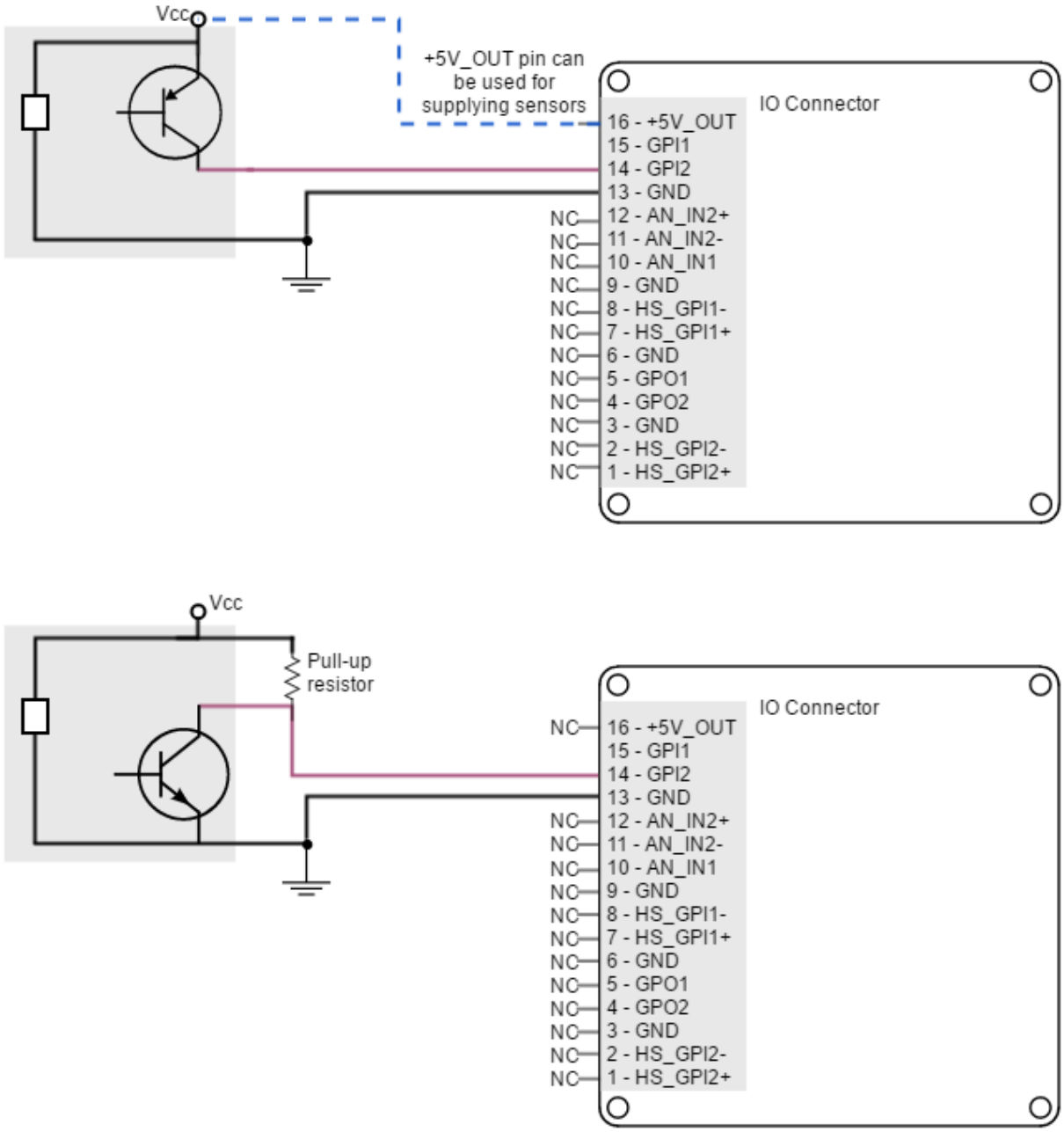
Next figure shows an example of how to connect a switch to the GPI, using +5V_OUT (pin 16) pin as a supply source.



Non-isolated I/O

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

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



GPI Pull-up resistors

Pull-up resistors ensure the desired logic state when the sensor (transistor or relay) is in off-state. NPN pull-up resistor value must be chosen in order to ensure ≥ 4 V at the GPI pin considering the 30 kΩ input resistance. For a sensor supply of 5 V, 1 kΩ is recommended. For a sensor supply of 24 V, 10 kΩ is recommended.

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

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

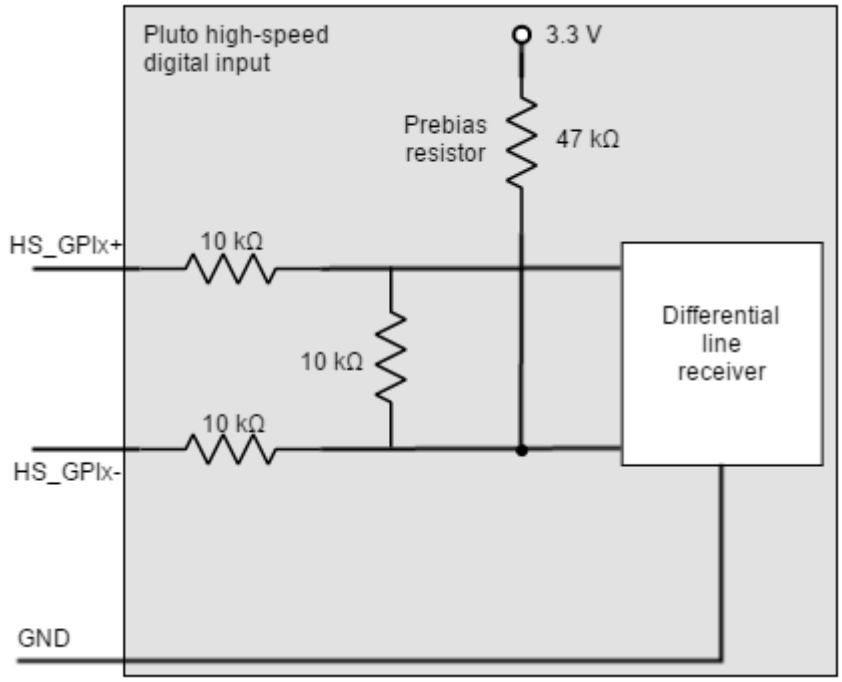
Defect logic value

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

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

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-.

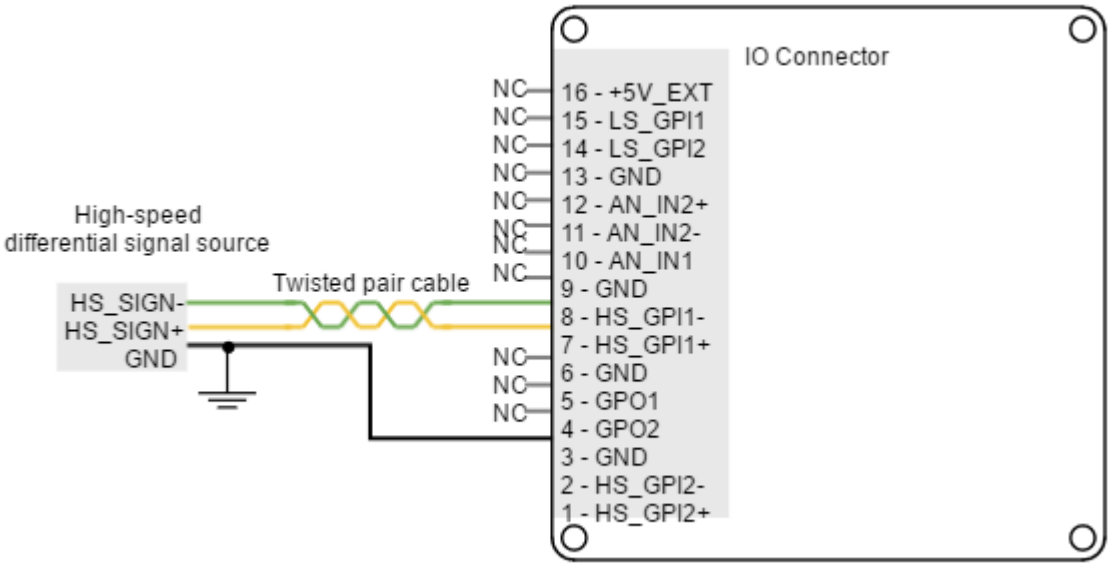
High-speed digital inputs electrical equivalent circuit is the following:



Non-isolated I/O

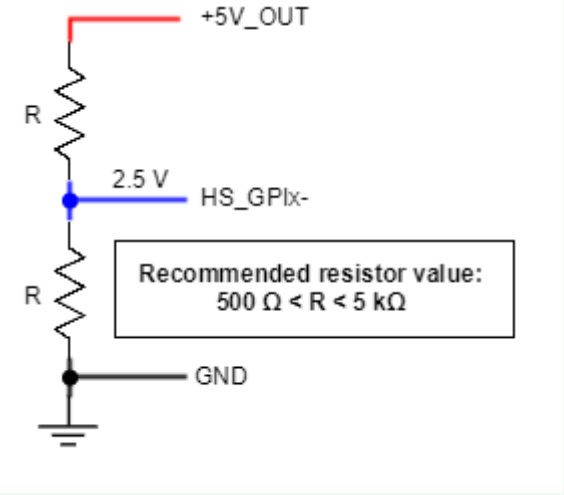
Pluto Inputs and outputs are not isolated. The ground of the Pluto Servo Drive and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

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



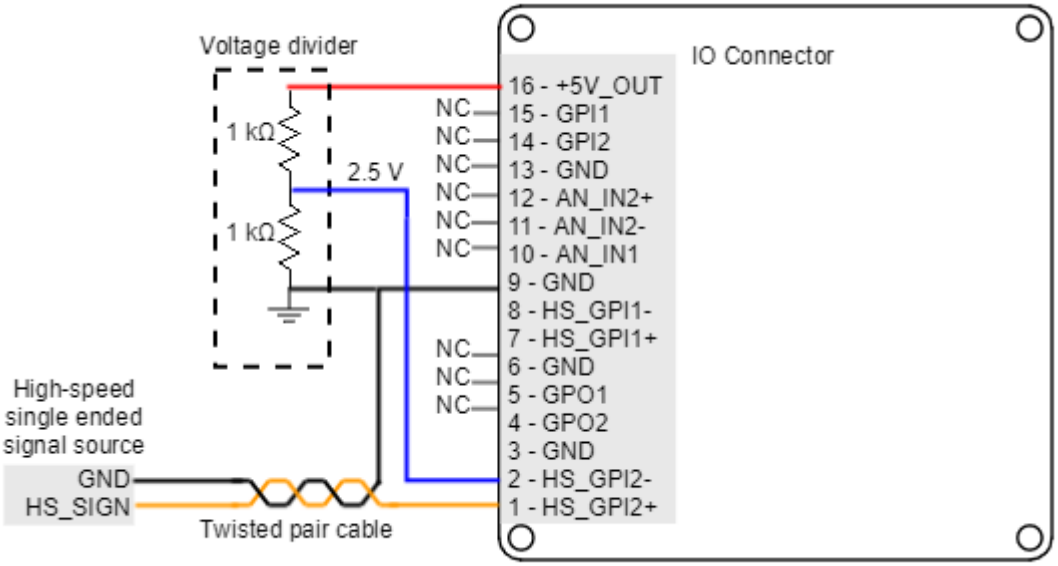
Single ended operation

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

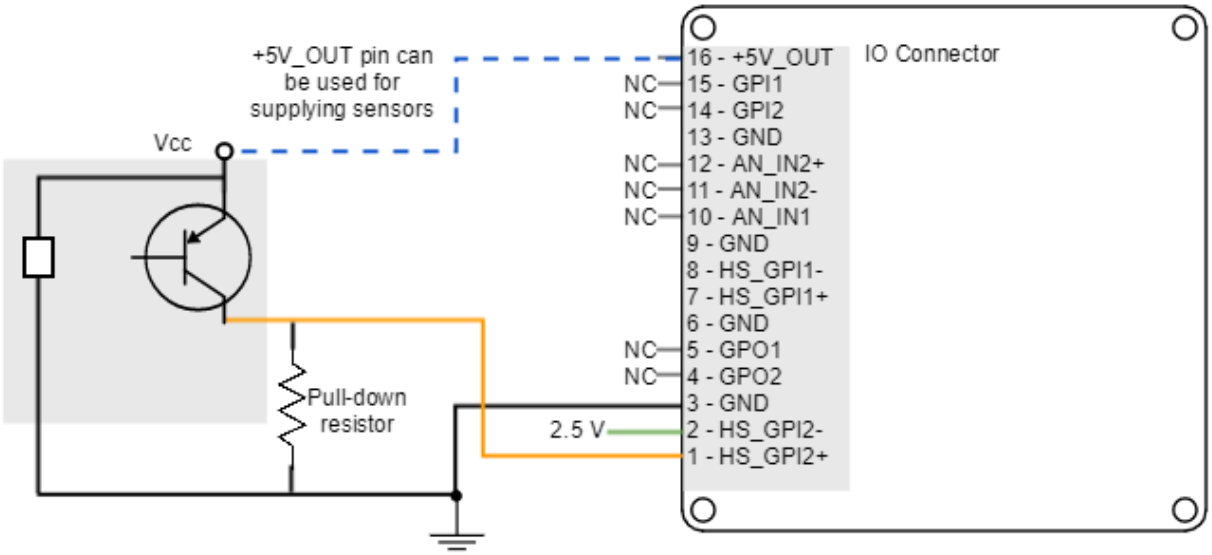


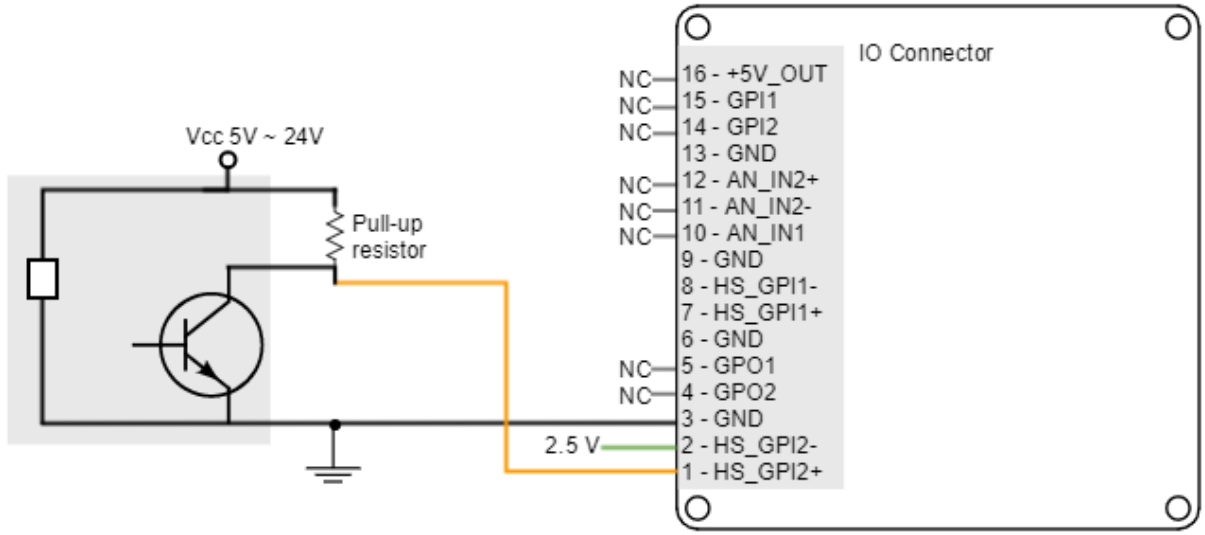
For a 24 V input, the negative terminal **(HS_GPIx-)** can be connected to 5 V (+5V_OUT).

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



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

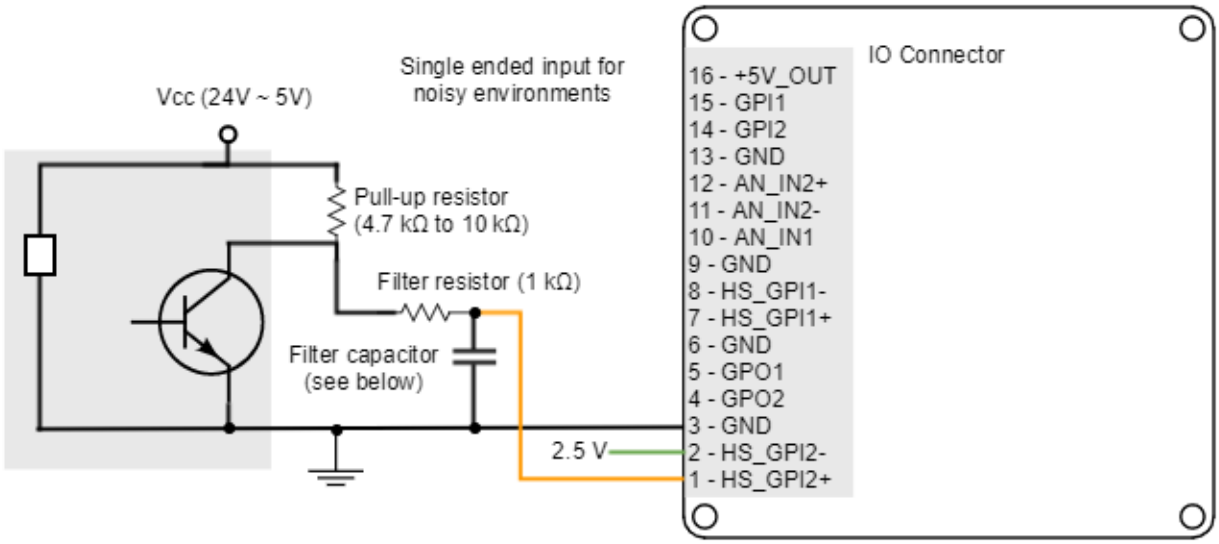




HS_GPI pull-up and pull-down resistors

Pull-up and pull-down resistors ensure the desired logic state when the sensor (transistor or relay) is in off-state.
NPN pull-up resistor value must be chosen in order to ensure a positive value in the differential receiver while consuming low current. For a sensor supply of 5 V, 10 kΩ is recommended. For a sensor supply of 24 V, 100 kΩ is recommended.
PNP pull-down resistor value is not critical. It should be calculated to consume low current when the sensor is on-state. A 10 kΩ resistor is recommended.

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



Calculation of the filter capacitor

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

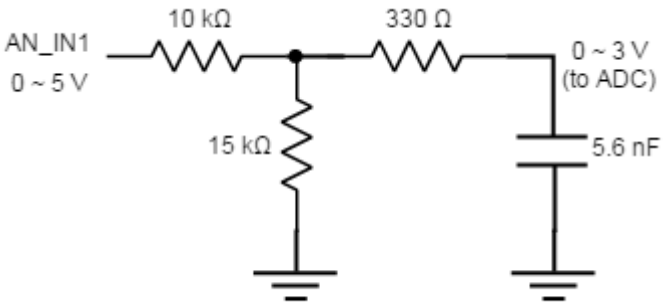
7.5.3 Analog inputs interface (AN_IN1, AN_IN2)

Pluto 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:

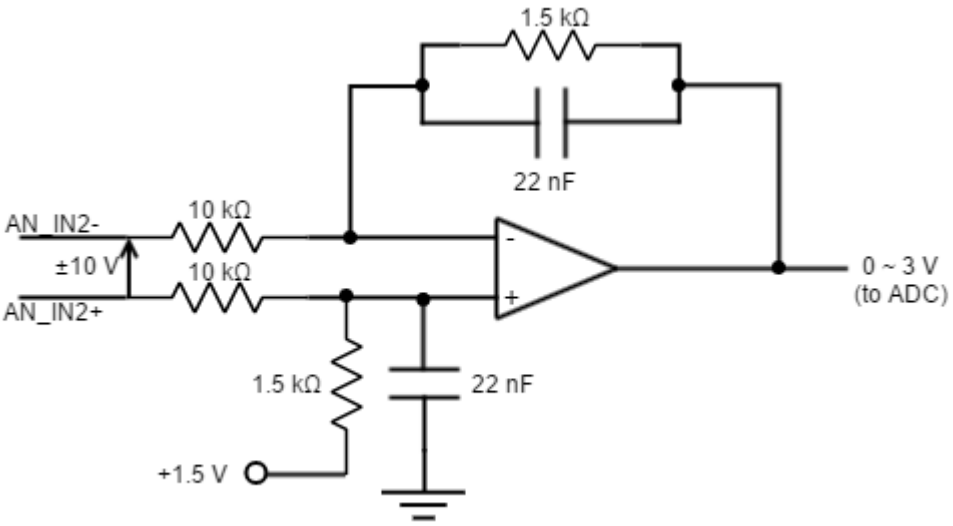
Specification	**Analog input 1**	**Analog input 2**
Type of inputs	Single ended ESD protected	Differential ESD protected
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)	
Analog input resolution	12 bits	
Maximum operating voltage	0 ~ 5 V	±10 V
Maximum common mode voltage (Analog input 2)	-	±10 V
Maximum voltage on any pin (referred to GND)	24 V	
1st order filter cutting frequency (-3 dB)	4.5 kHz	4.8 kHz

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

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



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



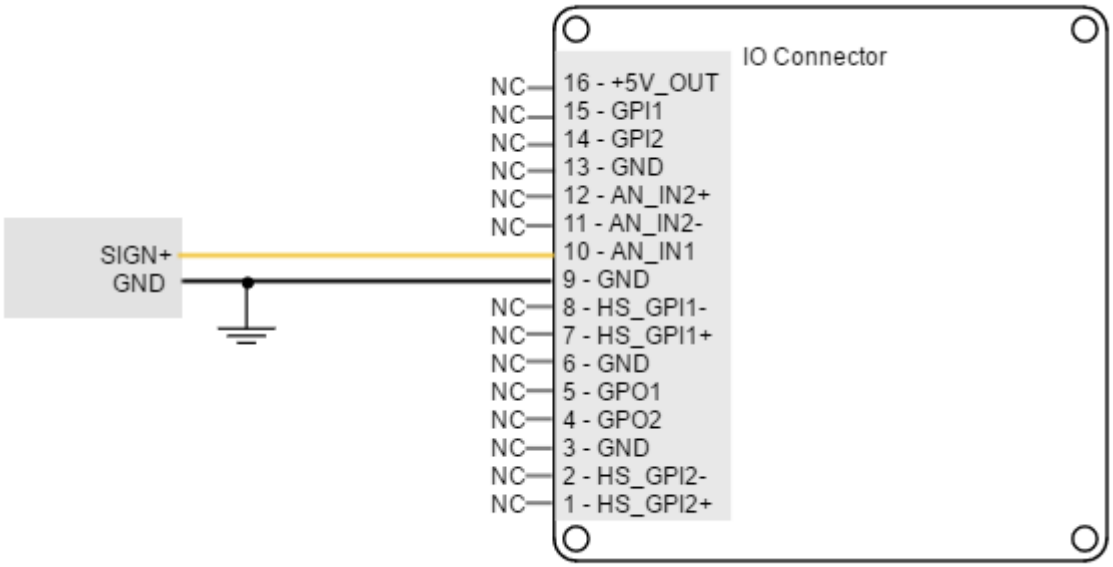
Extending AN_IN1 voltage range

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

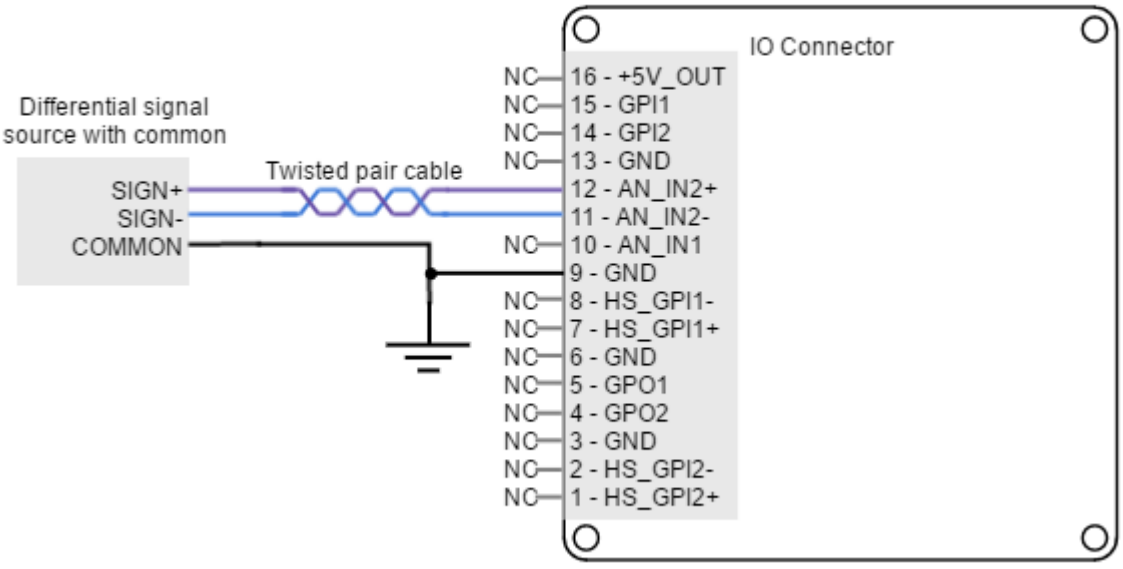
Non-isolated I/O

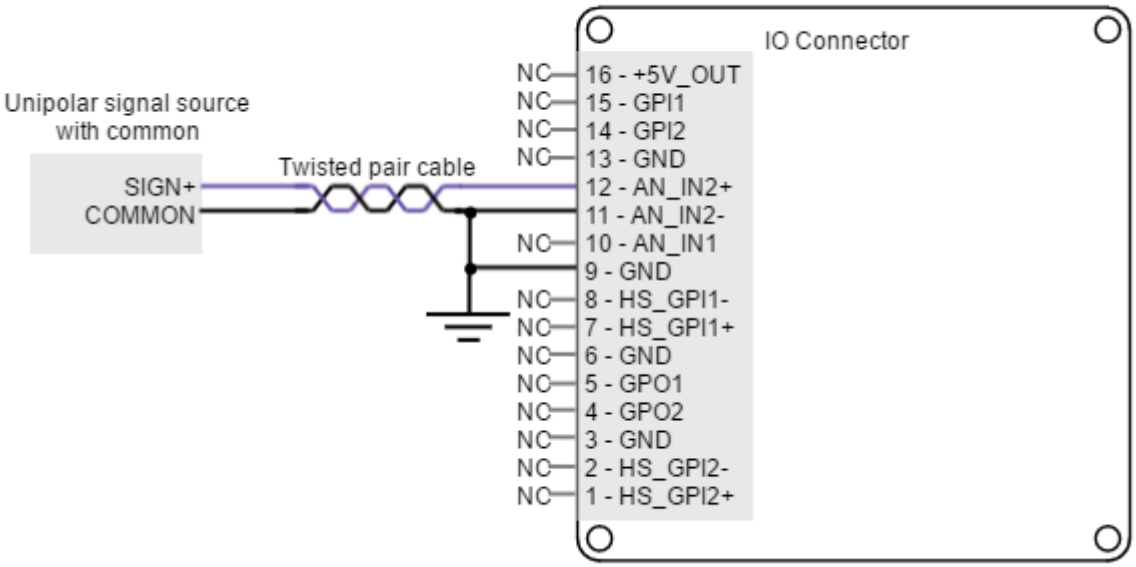
Pluto Inputs and outputs are not isolated. The ground of the Pluto Servo Drive and the ground of the devices connected to I/Os must be the same. Otherwise inputs or outputs may be damaged.

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



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





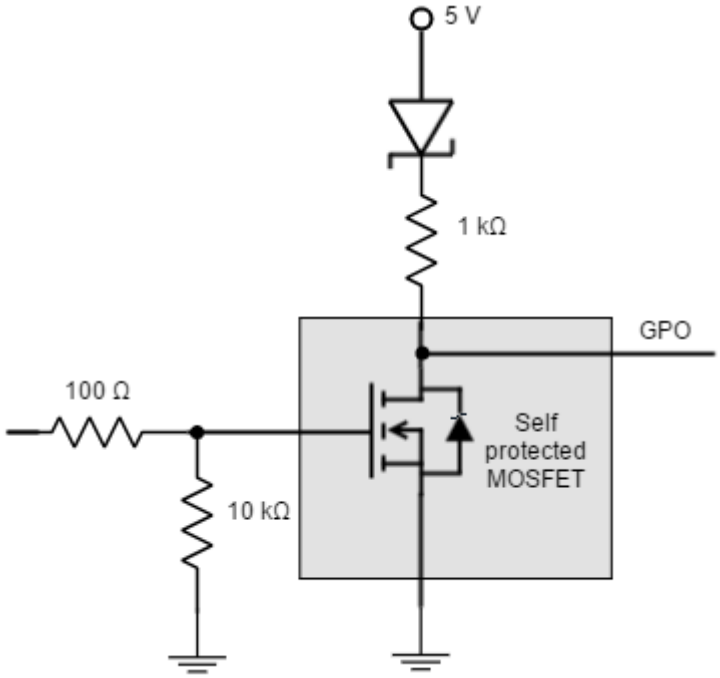
7.5.4 Digital outputs interface (GPO1, GPO2)

Pluto 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

Specification	Value
Max working frequency	1 kHz

Next figure shows digital outputs circuit model.

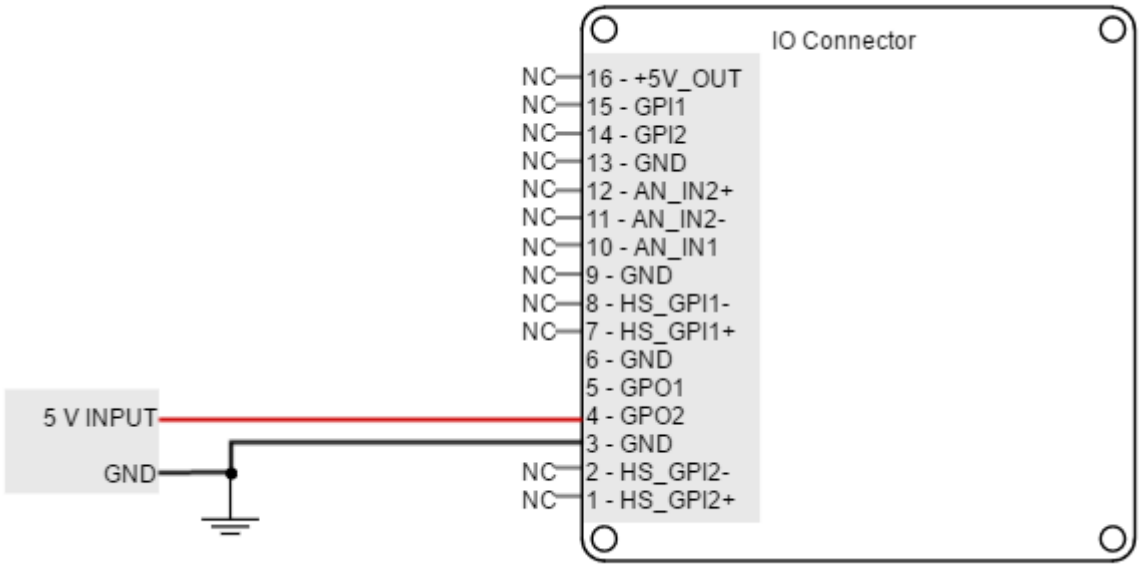


Non-isolated I/O

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

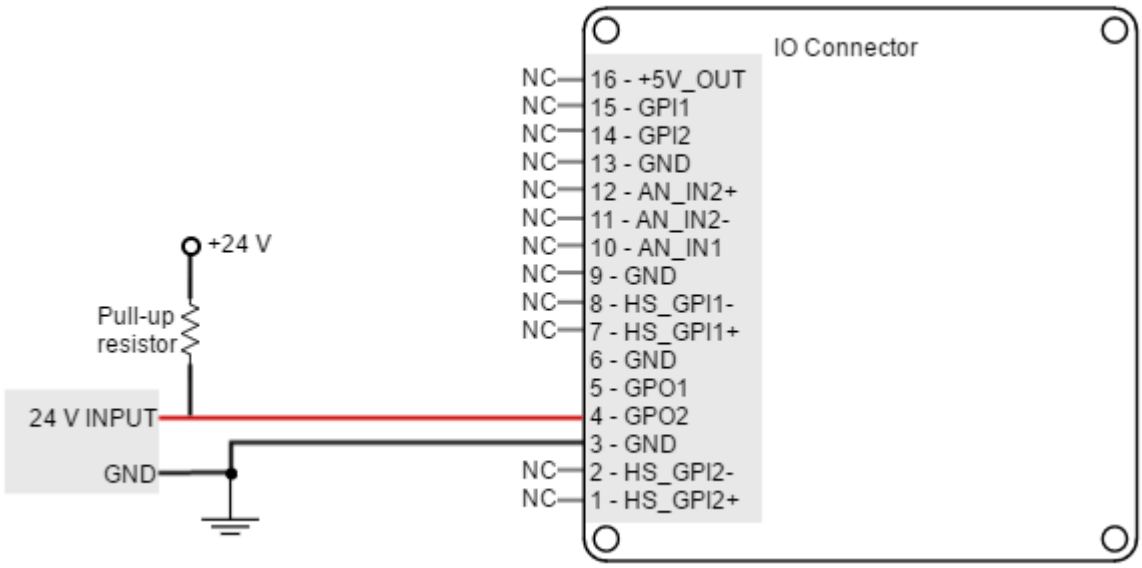
7.5.4.1 Wiring of 5V outputs

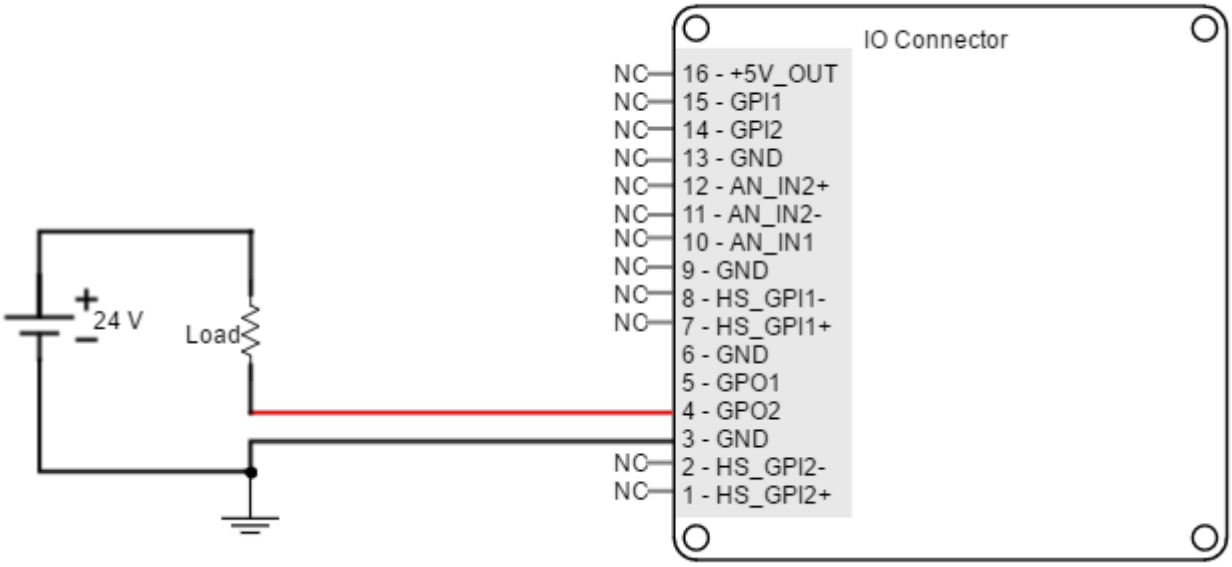
Loads that require 5V as high-level voltage can be connected directly to the digital output. A wiring example for GPO2 is shown in the next figure (same wiring could be used for GPO1).



7.5.4.2 Wiring of 24V loads

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

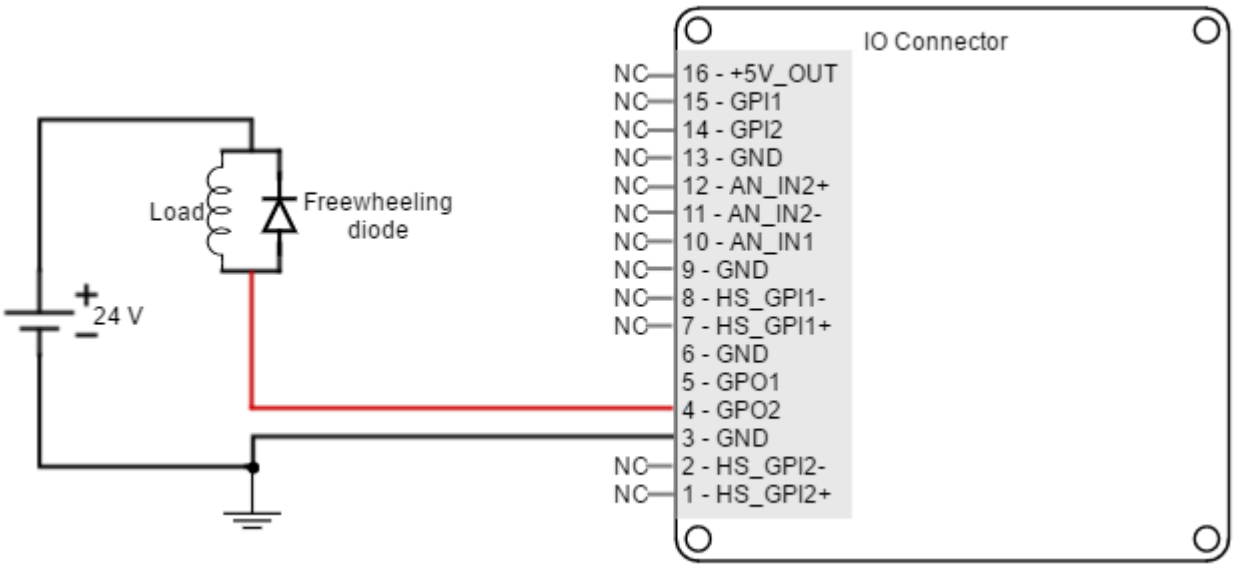




Interfacing inductive loads

The switching of inductive loads (like relays or motor brakes) can cause inductive kicking, that is a sudden voltage rise when the current through the inductor is falls to zero. In order to avoid this voltage rise, **it is recommended to place a diode in anti-parallel with the load** (known as freewheeling diode).
Standard rectifier diodes such as 1N4002 or 1N4934 are appropriate for the application.
An alternative to the freewheeling diode is to place a varistor or an RC snubber in parallel with the load.

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



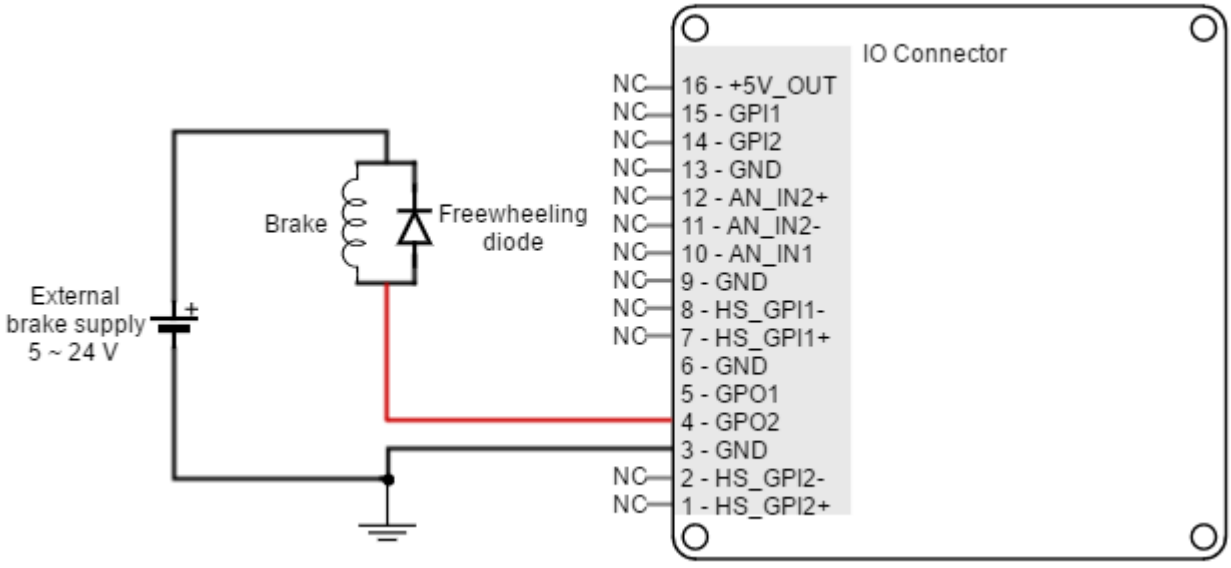
7.5.5 Motor brake output (GPO1, GPO2)

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

Motor brake operation

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

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



Free-wheeling diode

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

7.5.6 Torque off input (custom purchase order)

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

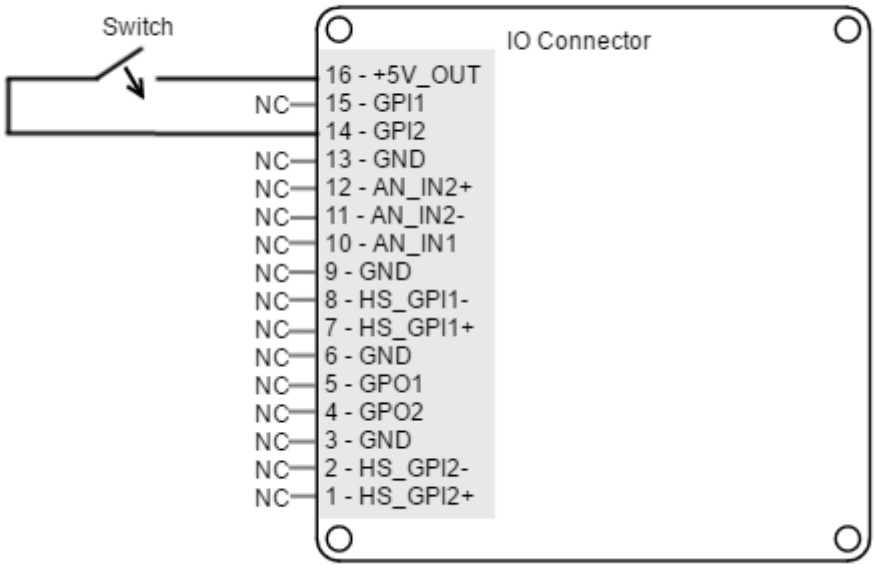
The torque off input can be implemented through input **GPI2**. When a **LOW level** voltage is detected in this input, **the transistors of the power stage are turned off** and a STO fault is notified. This is performed by disconnecting the power supply of the gate drivers of all the power transistors. Therefore, no matter the state of the firmware or software the transistors will be deactivated.

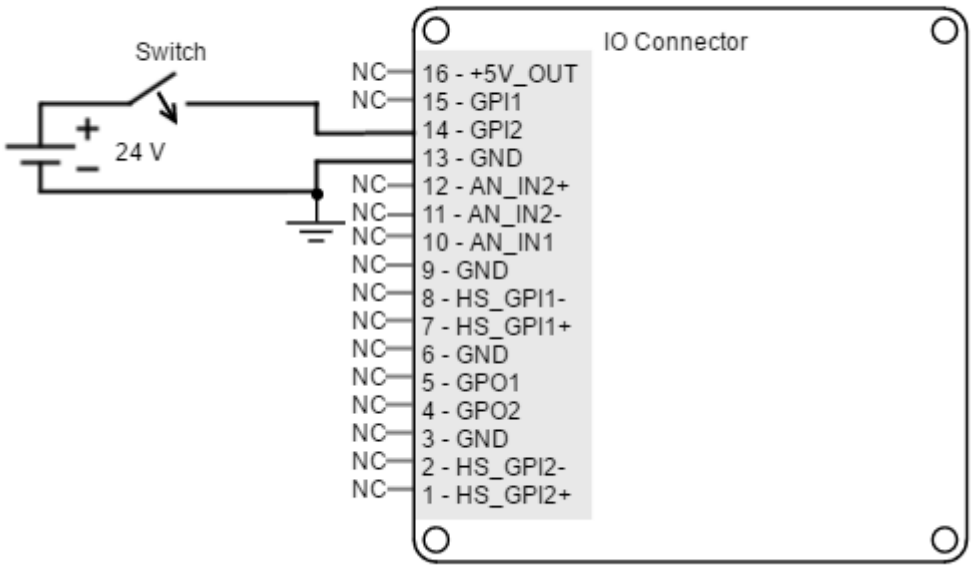
During this state, no torque will be applied to the motor no matter configuration, or state of a command source. This will slow down the motor shaft until it stops under its own inertia and frictional forces. This input should not be confused with a digital input configured as enable input, because enable 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 certified torque off input (Safe Torque Off). Therefore it is not intended to be used in 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.




Switch
24 V
IO Connector
NC
16 - +5V_OUT
NC
15 - GPI1
14 - GPI2
13 - GND
NC
12 - AN_IN2+
NC
11 - AN_IN2-
NC
10 - AN_IN1
NC
9 - GND
NC
8 - HS_GPI1-
NC
7 - HS_GPI1+
NC
6 - GND
NC
5 - GPO1
NC
4 - GPO2
NC
3 - GND
NC
2 - HS_GPI2-
NC
1 - HS_GPI2+

7.6 Command sources

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

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

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

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

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

7.6.1 Network communication interface

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

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 EtherCAT. These interfaces are more robust against noise than USB, and allow higher distances between the Pluto Servo Drive and the commander. These command sources can be used for setting position, velocity or torque target.

For further information, see Communications section.

7.6.2 Standalone

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

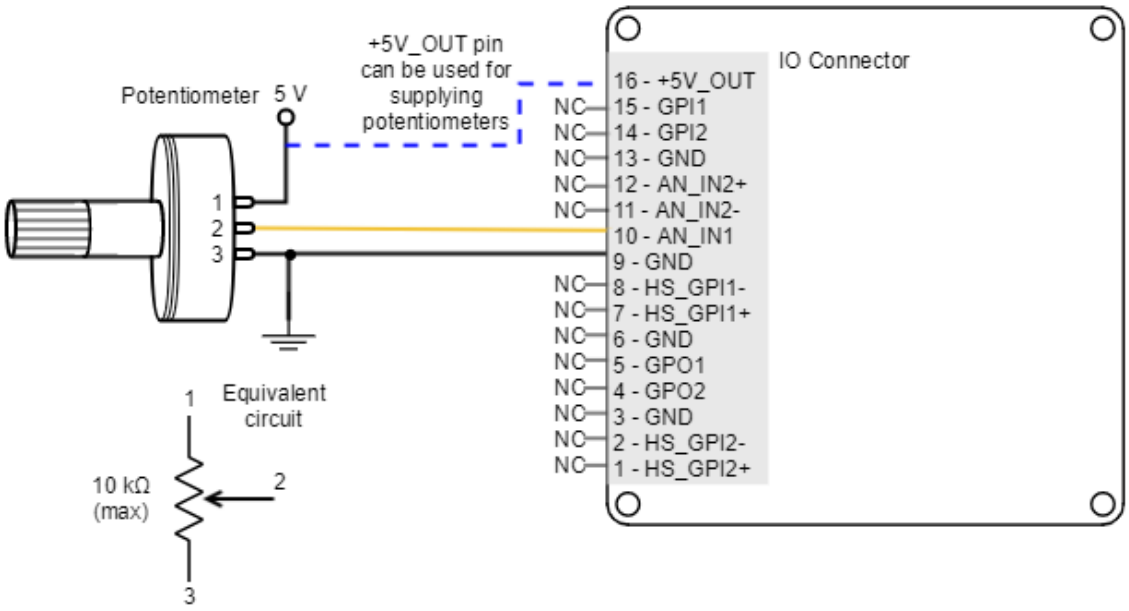
Programs or macros composed with Motion Lab suite allow to **configure position, velocity or torque targets** and to **interface with general purpose inputs and outputs.**

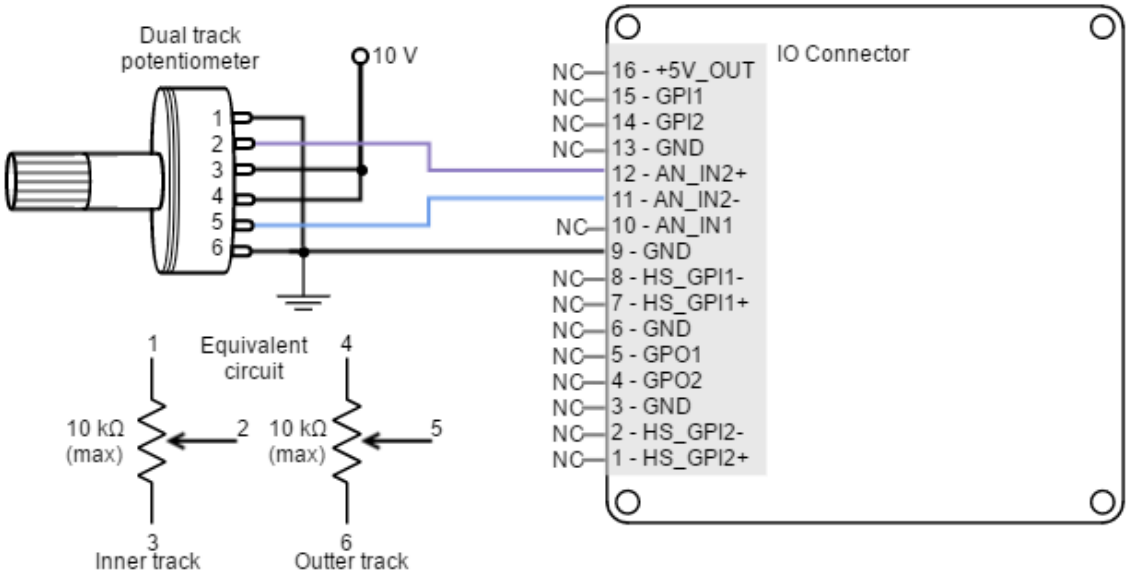
This feature can be very useful in applications such as production lines or test equipment, where repetitive movements are usual. Please refer to MotionLab documentation for further information.

7.6.3 Analog input

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

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

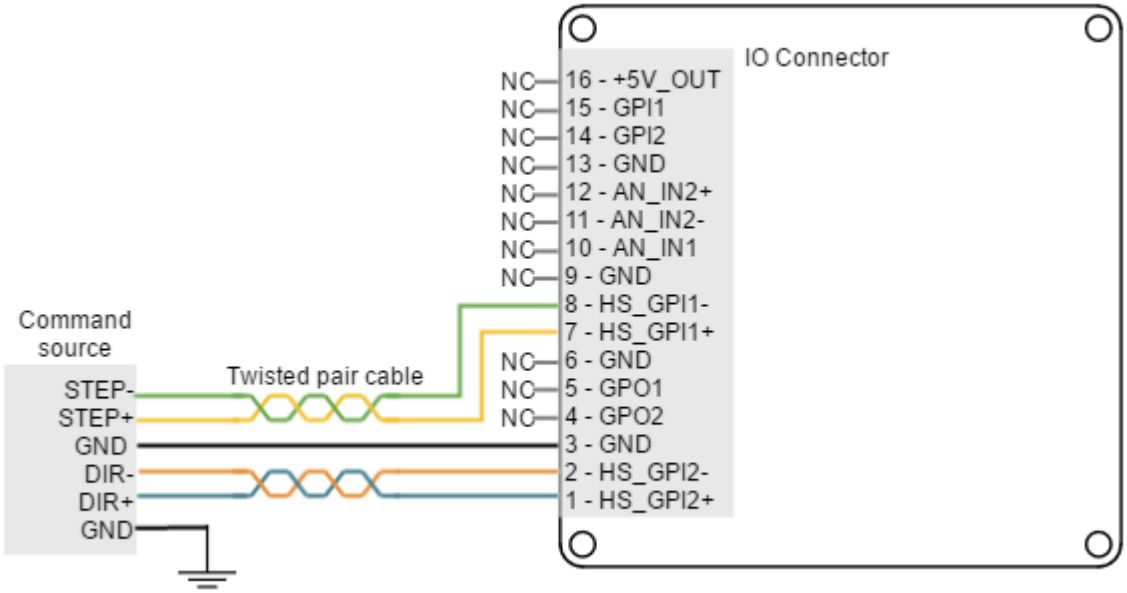




7.6.4 Step and direction

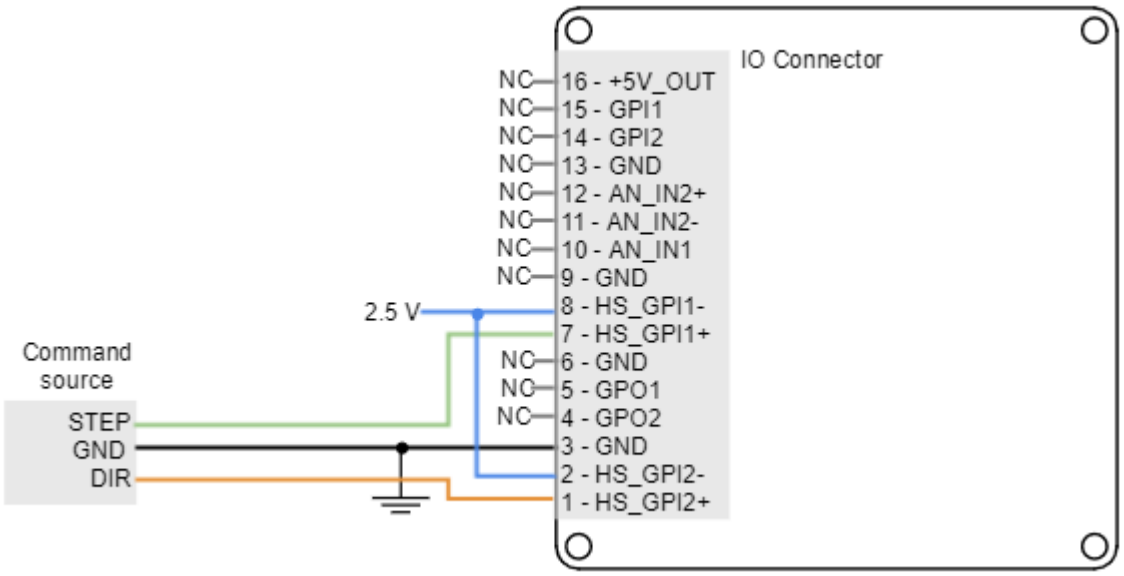
For this command source, the drive typically accepts two digital inputs from an external source: Step (pulse) and Direction. Direction signal sets the direction of rotation (i.e., logic low or "0" for clockwise rotation and logic high or "1" for counter-clockwise rotation). Pulse signal is usually a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

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



Single ended operation

In order to use the high-speed digital input in **single ended mode**, **connect the negative terminal (HS_GPIx-) to 2.5 V**. This voltage can be achieved with a voltage divider from +5V_OUT.
For a 24 V input, the negative terminal **(HS_GPIx-)** can be connected to 5 V (+5V_OUT).



7.6.5 PWM command

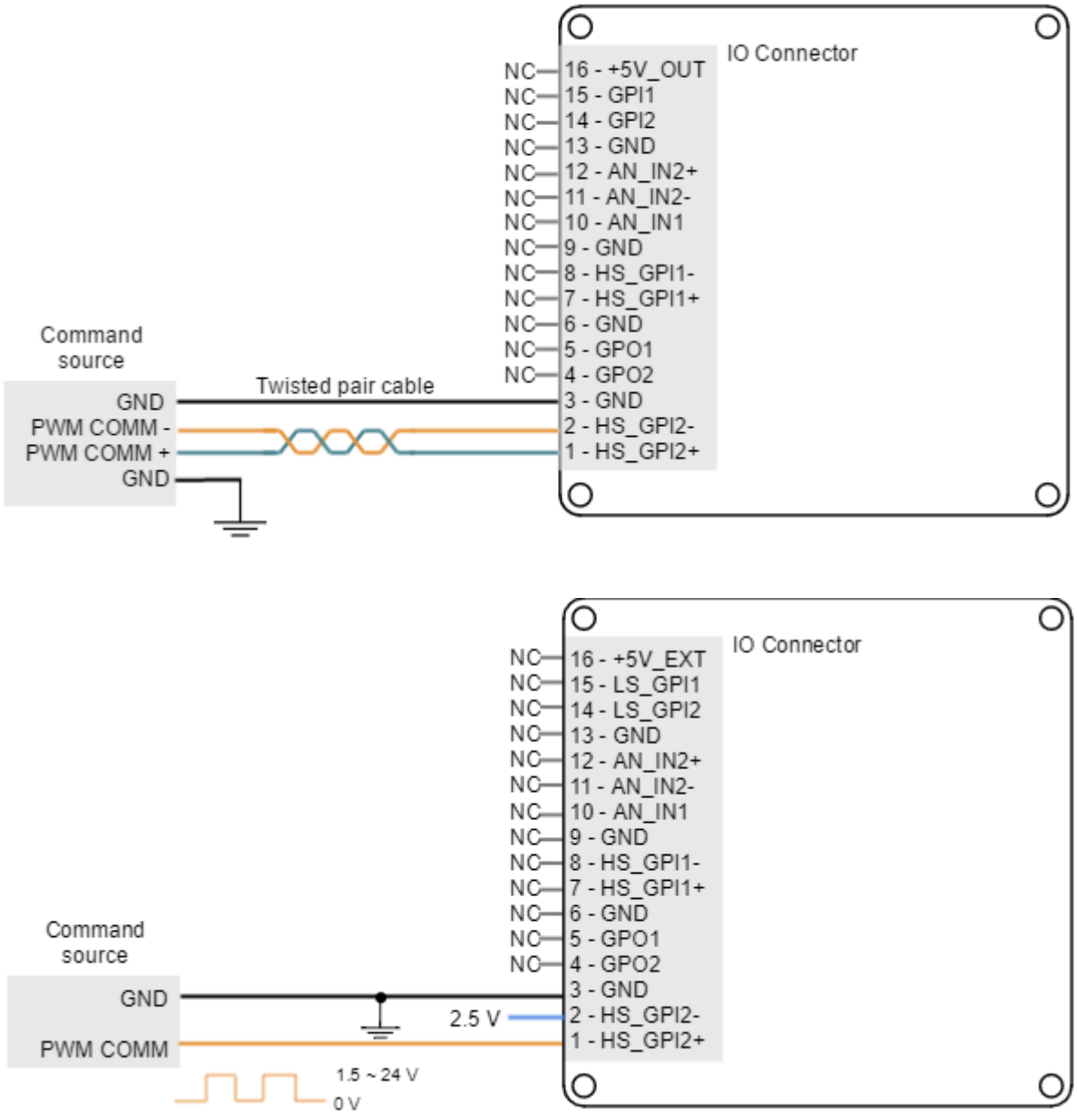
PWM command source sets a position, velocity or torque target from the duty cycle value of a PWM signal. PWM command has to be interfaced with the **high-speed digital input 2 (HS_GPI2)**. Further details about this input can be seen in I/O Connections page. PWM command sources with single and dual input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

It is recommended to use a PWM frequency between **2 kHz and 20 kHz**. Higher frequencies could be read but will lead to a lower resolution with no improvement in performance. Frequencies below 2 kHz can lead to control problems.

7.6.5.1 Single input mode

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

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



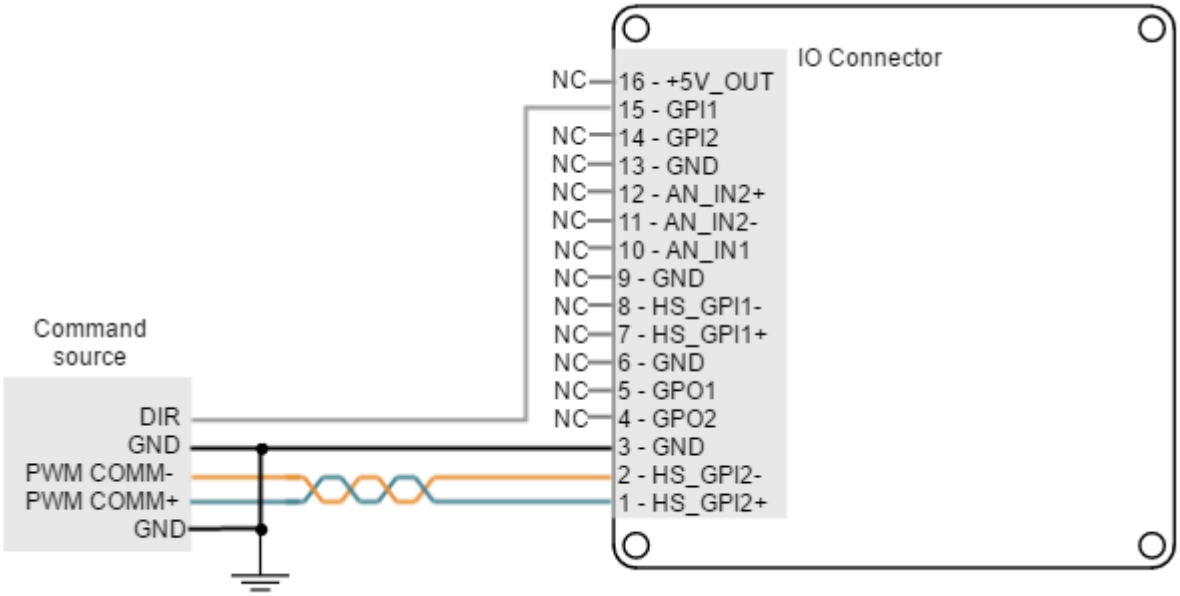
7.6.5.2 Dual input mode

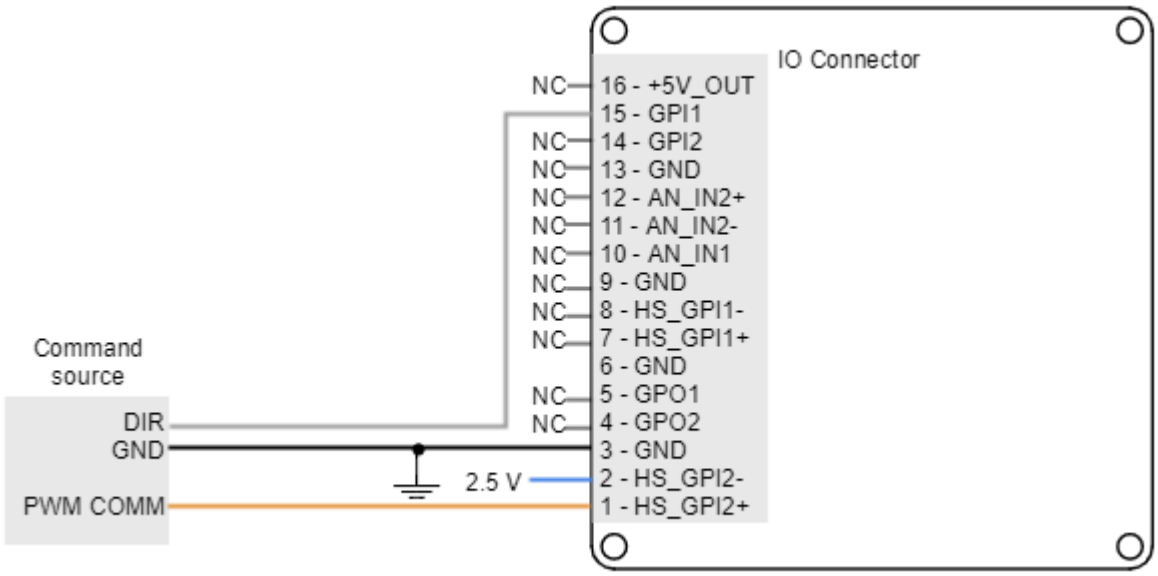
Dual input mode uses two signal lines, a PWM signal whose duty cycle sets the target position, velocity or torque, and a Direction signal that indicates the rotation direction (i.e., logic low or "0" for clockwise rotation and logic high or "1" for counter-clockwise rotation). In this mode, a duty cycle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

Two general purpose inputs are used:

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

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



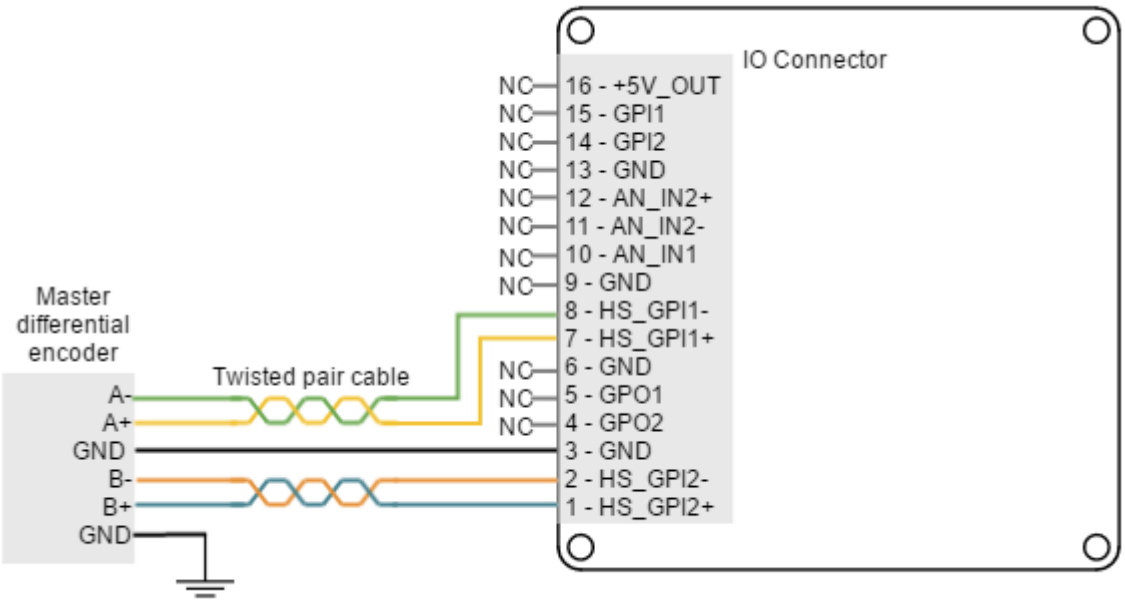


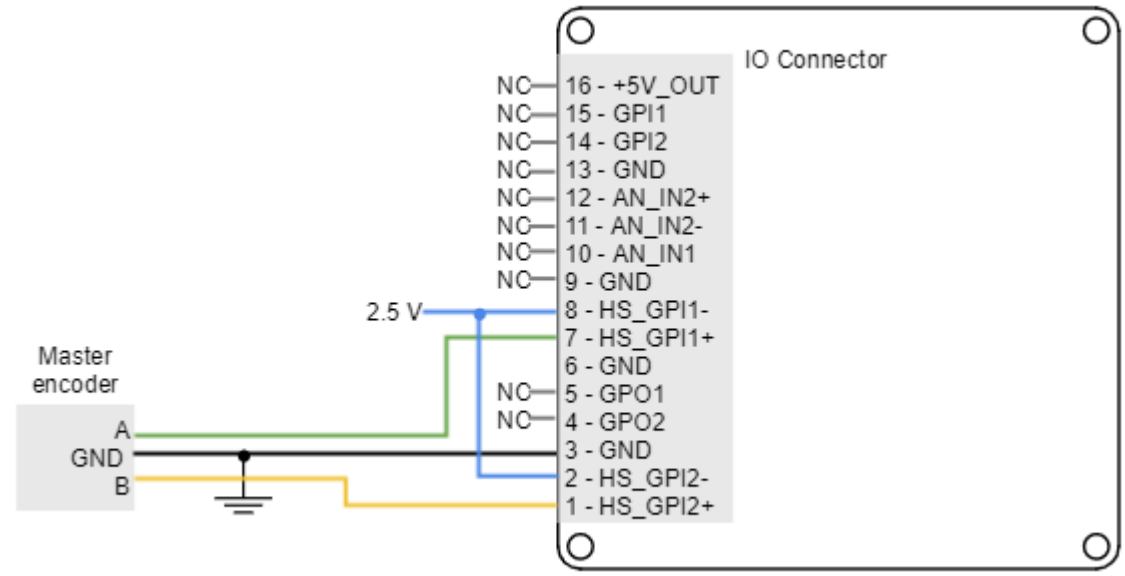
7.6.6 Encoder following or electronic gearing

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

Encoder following command source is implemented by connecting the input encoder (auxiliary encoder of the master motor) to high-speed digital inputs (HS_GPI). Encoder channel A must be connected to high speed digital

input 1, and channel B to high speed digital input 2. Connection examples for the differential and single ended master encoders are shown in the next figures:





7.7 Communications

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

- USB
- CANopen
- EtherCAT

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

7.7.1 USB interface

Pluto 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.

Power supply for configuration

Power supply has to be provided for configuration purposes. Pluto Servo Drive can not be supplied from USB connector.

7.7.1.1 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 Pluto.
- Do not rely on an earthed PC to provide the Pluto Servo Drive earth connection. The drive must be earthed through a separate circuit.
- Avoid creating ground loops by using isolated power supplies.
- Shortest cables are preferred.

7.7.2 CANopen interface

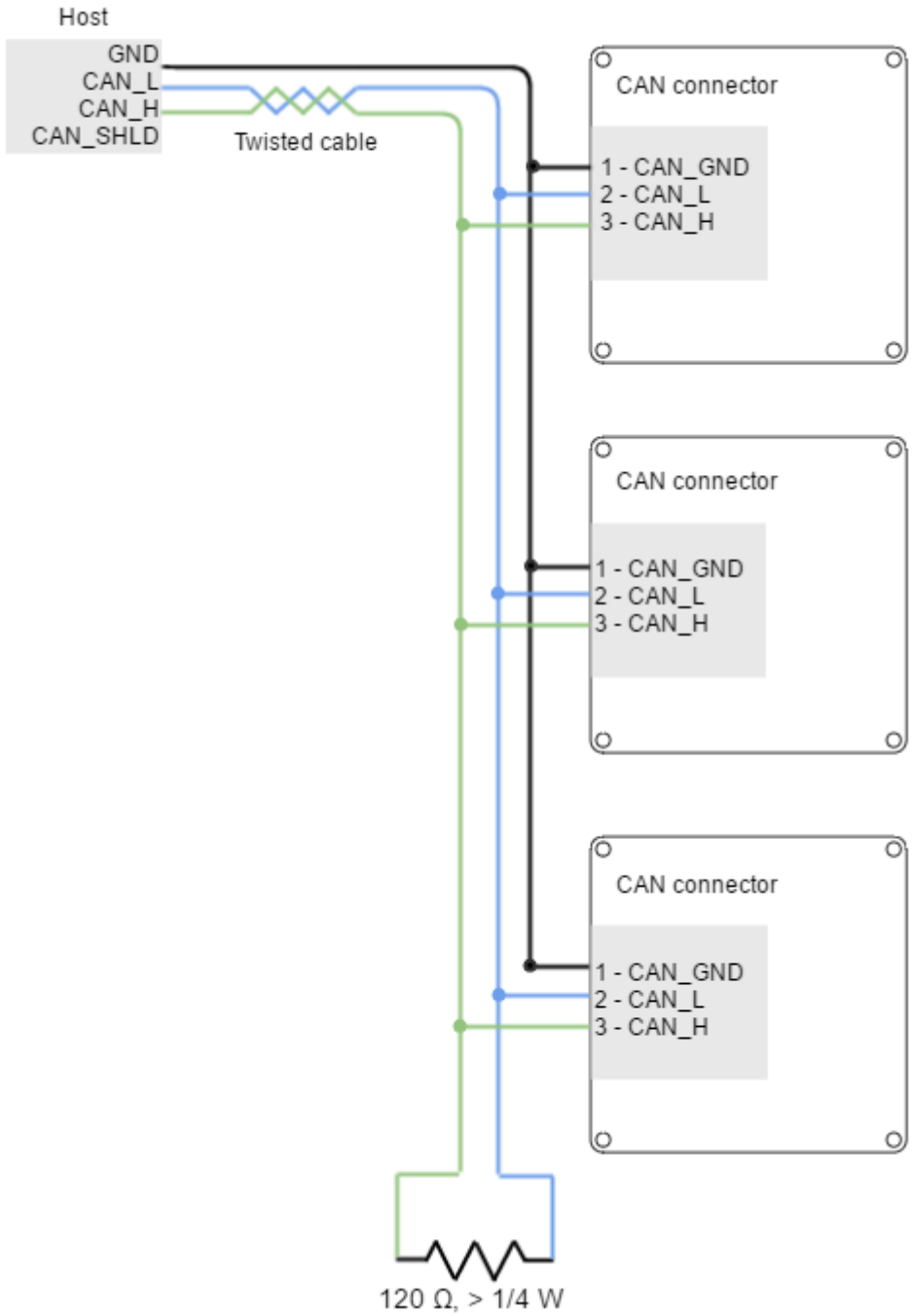
Pluto Servo Drive supports CANopen interface, a multi-terminal communication protocol based on CAN (Controller Area Network) bus. Pluto CAN interface is not isolated. Main physical specifications are shown in the next table:

Specification	Details
Interface	Versions 1.x.x and 2.x.x: **Non-isolated.** Self-supplied (no need for external supply) Versions 3.0 onwards. **Isolated**, self-supplied (no need for external supply)
Isolation	Versions 1.x.x and 2.x.x: None. Versions 3.0 onwards: Isolated, 1500 VDC. Reinforced insulation at Pollution degree 2.
Protection	Versions 1.x.x and 2.x.x: CAN bus fault ±36 V. ESD / Burst Versions 3.0 onwards: CAN bus fault ± 60 V. ESD / Burst / Surge.
Baud rate	From 125 kbps to 1 Mbps (default value)
Maximum number of nodes	64
Termination resistor	Not included on board. 120 Ω terminations must be wired externally at the ends of the bus.

Drive ID

When installing CANopen communication, ensure that each servo drive is allocated a unique ID. Otherwise, the 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 Pluto connected, mount the termination resistor to ensure CAN bus operation. **Do not use wire-wound resistors**, which are inductive. When the bus is properly wired, the parallel differential resistance of the CAN bus should be ~ 60 Ω. Check this resistance with a multimeter to ensure that everything is correctly wired and terminated.

7.7.2.1 CAN interface for PC

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

Some recommended CAN transceivers are shown below:

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

7.7.2.2 CAN wiring recommendations

- Build CAN network using cables with **2-pairs of twisted wires** (2 wires/pair) as follows: one pair for CAN_H with CAN_L and the other pair for CAN_V+ with CAN_GND.
- Cable impedance must have an impedance of 105 to 135 Ω (120 Ω typical) and a capacitance below 30 pF/meter.
- Whenever possible, use bus links between the CAN nodes. **Avoid using stubs** (a "T" connection, where a derivation is taken from the main bus). If stubs cannot be avoided keep them as short as possible. For maximum speed (1 Mbps), use a stub length lower than 0.3 meters.

- For a total CAN bus length **over 40 meters**, it is mandatory to **use shielded twisted cables**. Connect the cable shield to protective earth at both ends (non isolated version), or to CAN_GND (isolated version). Ensure that the cable shield is connected to the connector shield, as connection to host protective earth is usually soldered inside the connector.

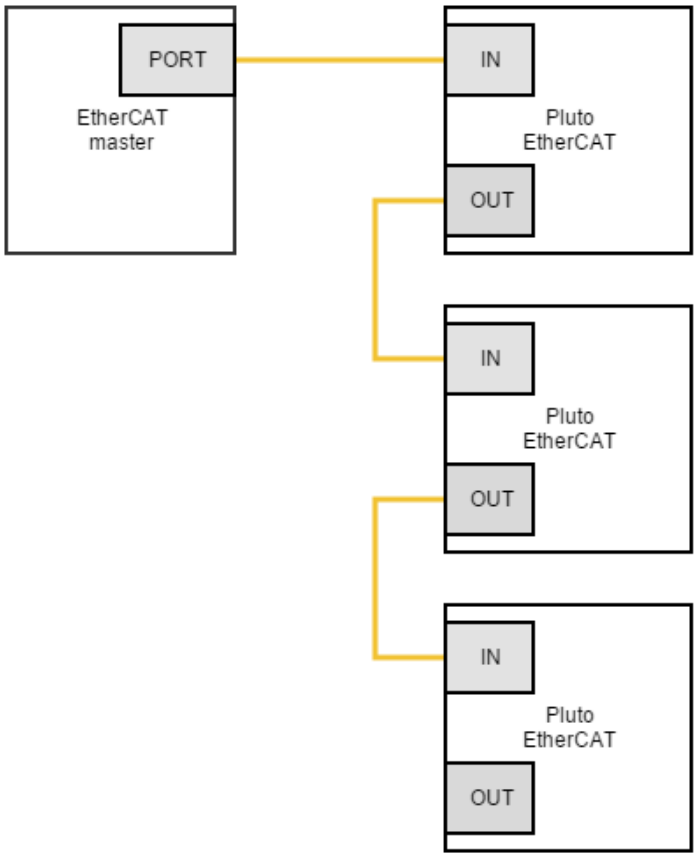
7.7.3 EtherCAT interface

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

Next table summarizes the features of the Pluto EtherCAT interface.

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

Next figure shows a wiring diagram of an EtherCAT bus.


PORT
EtherCAT
master
IN
Pluto
EtherCAT
OUT
IN
Pluto
EtherCAT
OUT
IN
Pluto
EtherCAT
OUT

8 Dimensions

The Pluto Servo Drive is available in different versions, which present 2 different dimensions specifications:

- PLU-x/xx-S and PLU-x/xx-C (Pluto with USB and USB/CANopen)
- PLU-x/xx-E (Pluto with EtherCAT)

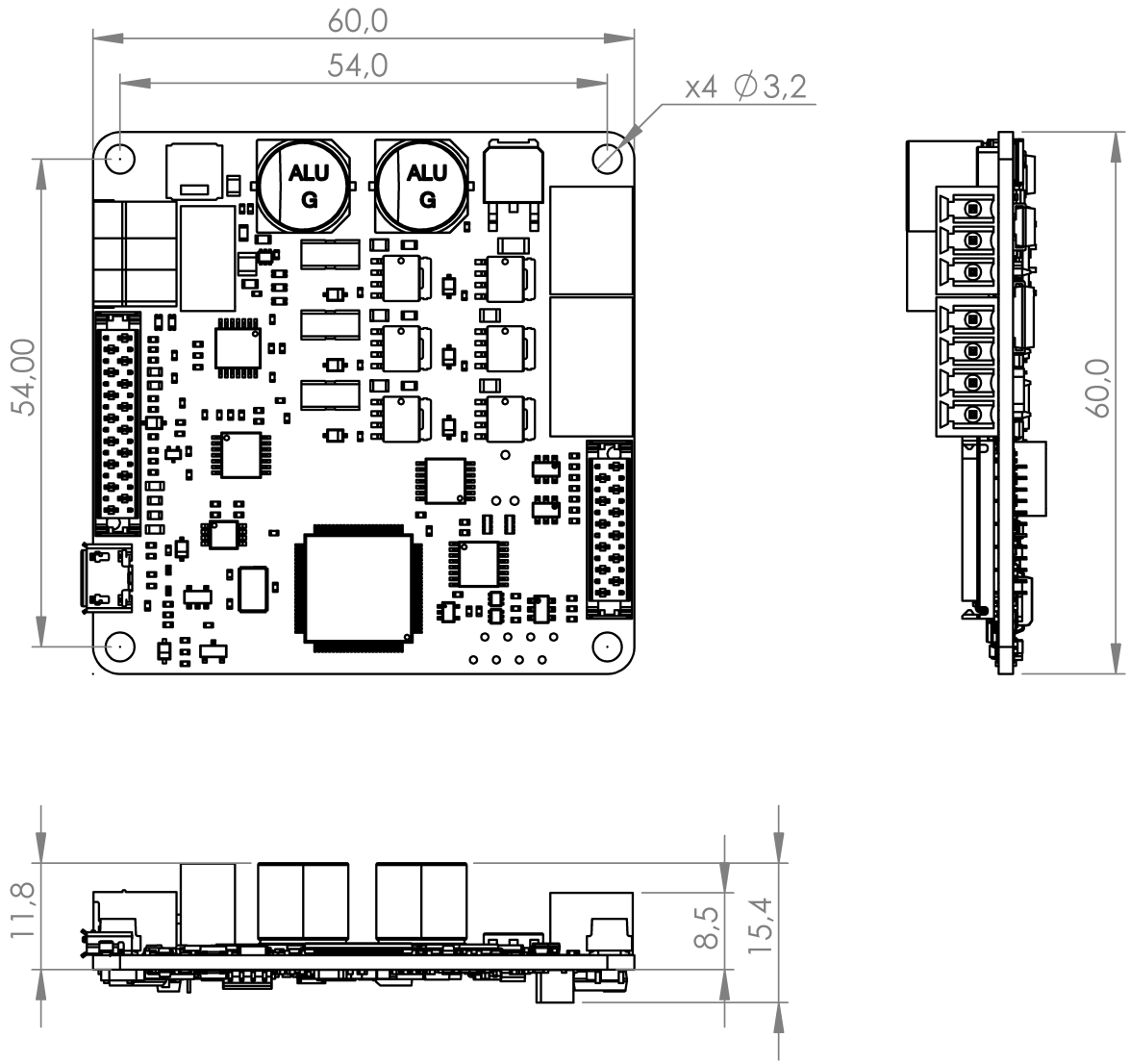
> **Fixation elements diameter ≤ 6 mm**
>
> Please do not use spacers, washers or nuts exceeding 6 mm external diameter as they could collide with some electrical parts.
> Also, take due precautions not to damage any components during assembly.

3D files can be downloaded here: http://distext.ingeniamc.com/products/PLU/steps/

8.1 PLU-x/xx-S and PLU-x/xx-C

Pluto Servo Drive versions PLU-x/xx-S and PLU-x/xx-C have a 60 mm x 60 mm footprint and a maximum 15 mm height. The drive is provided with 4 x Ø 3.2 mm holes for M3 standoff mounting and to allow mounting the EtherCAT Daughter Board and the IO Starter Kit. These holes are plated and connected to protective earth (PE).

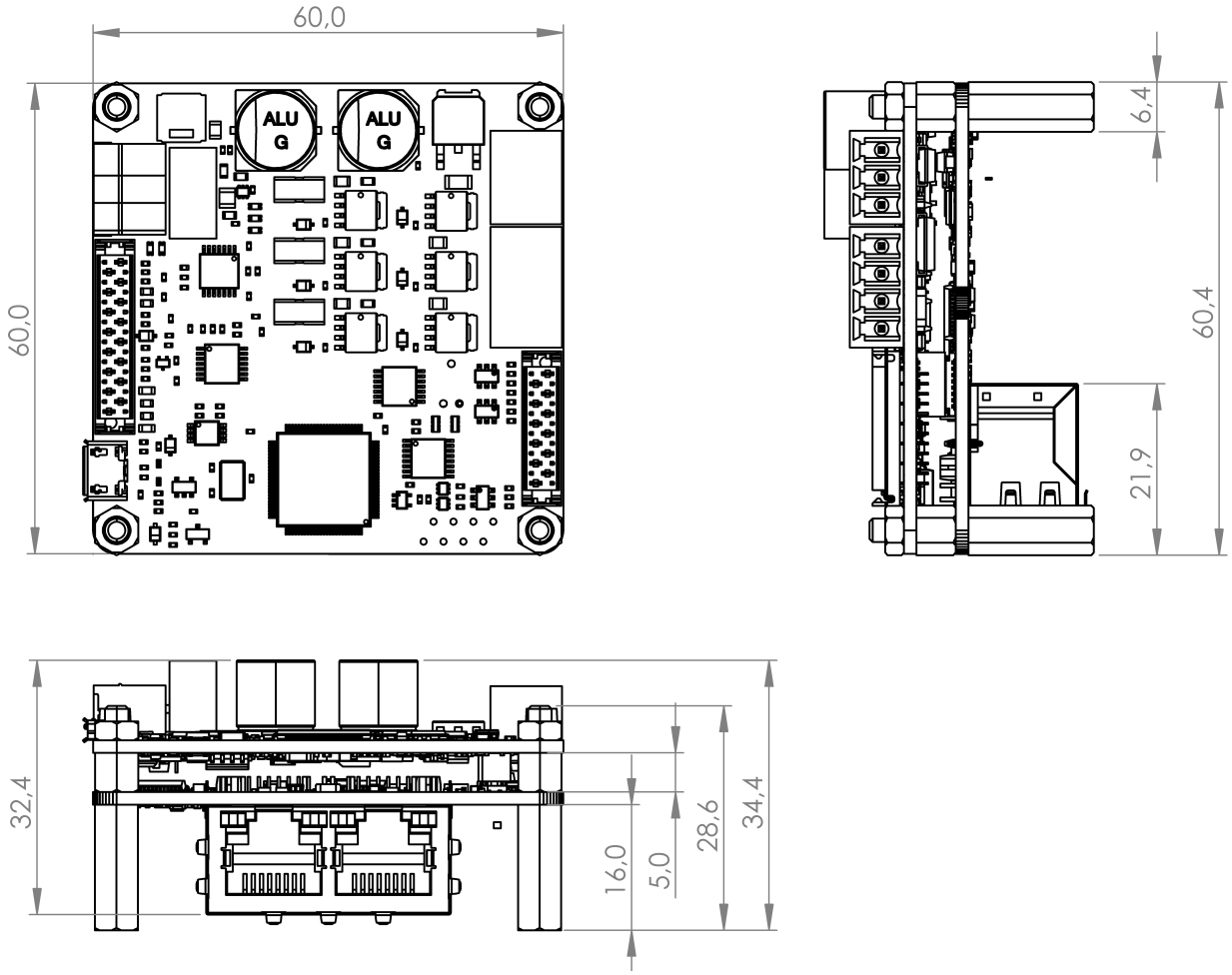
Next figure shows mechanical dimensions in **mm**. Tolerances **≤ ±0.2 mm**.



8.2 PLU-x/xx-E (Pluto with EtherCAT)

Pluto Servo Drive version PLU-x/xx-E has a 60 mm x 60 mm footprint and a maximum 34.6 mm height. The drive is provided with 4 x M3 standoff.

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


60,0
60,0
ALU
G
ALU
G
6,4
60,4
21,9
32,4
16,0
5,0
28,6
34,4

9 Software

9.1 Configuration

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

Keep the firmware updated

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

9.2 Applications

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

10 Service

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

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