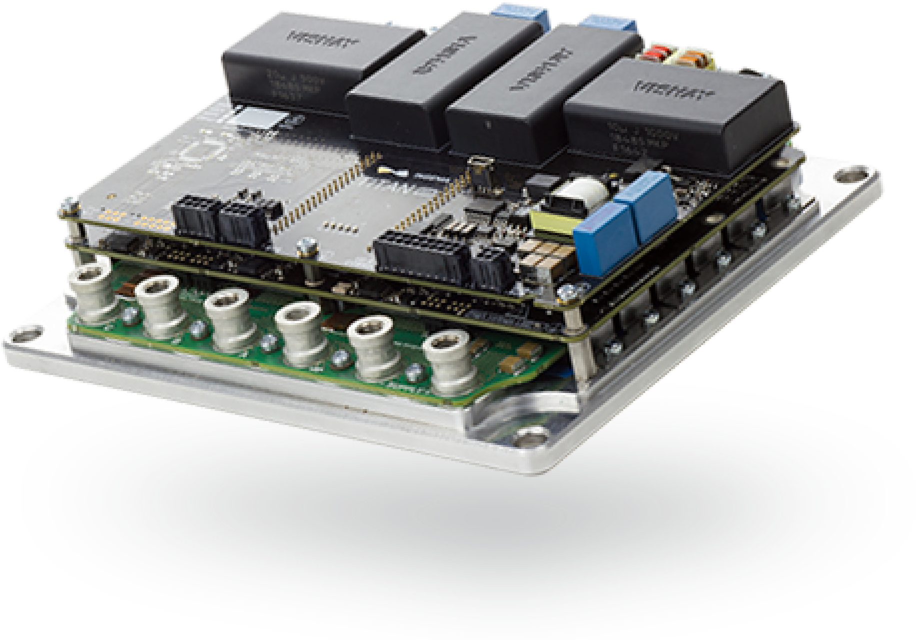
TITAN GO Product Manual



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INGENIA-CAT S.L.

C/ ÁVILA 124, 2ºB

08018 BARCELONA

INGENIA
passion for motion

1 Table of Contents

2 General Information

2.1 Manual revision history

Revision	Release Date	Changes	
v1	May 2017	Preliminary draft. All the information in this version could change without notice.	
v2	August 2017	Preliminary release. Added wiring guide, power ratings and updated mechanical drawings.	
v3	January 2018	Release version of the manual Includes changes according to product version 1.2.0.	
v4	February 2020	Minor corrections. Added PDF automatic exporter.	Download PDF

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

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2.3 Contact

INGENIA-CAT, S.L.
C/ Avila 124, 2-B
08018 Barcelona
SPAIN

Telephone: +34 932 917 682
E-mail: hello@ingeniamc.com
Web site: www.ingeniamc.com

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 Titan Servo Drive.

To ensure maximum safety in operating the Titan 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 Titan Servo Drive, as well as other hardware that may be connected to it. Please read this chapter carefully before starting the installation process.

3.2 Warnings

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

- **The Titan Go has no enclosure and has high voltage live parts**. Take precautions before commissioning or touching it. Direct contact with live parts can cause serious injury or death.
- To prevent the formation of electric arcs, as well as dangers to personnel and electrical contacts, never connect/disconnect the Titan Servo Drive while the power supply is on.
- The Titan manages high electrical power and the motors will have high mechanical power. To prevent damages to the setups or motors, **always tune and start testing with low torque and current limits**. Never start a configuration or setup with unlimited current settings.
- Disconnect the Titan 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 20 seconds before touching any parts of the controller that are electrically charged or might be hot.

3.3 Precautions

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

- The Titan Servo Drive components temperature may exceed 150 ºC during operation.
- Some components become electrically charged during and after operation.
- The power supply connected to this controller should comply with the parameters specified in this document.
- When connecting the Titan 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 Titan Servo Drive, check that all safety precautions have been followed, as well as the installation procedures.

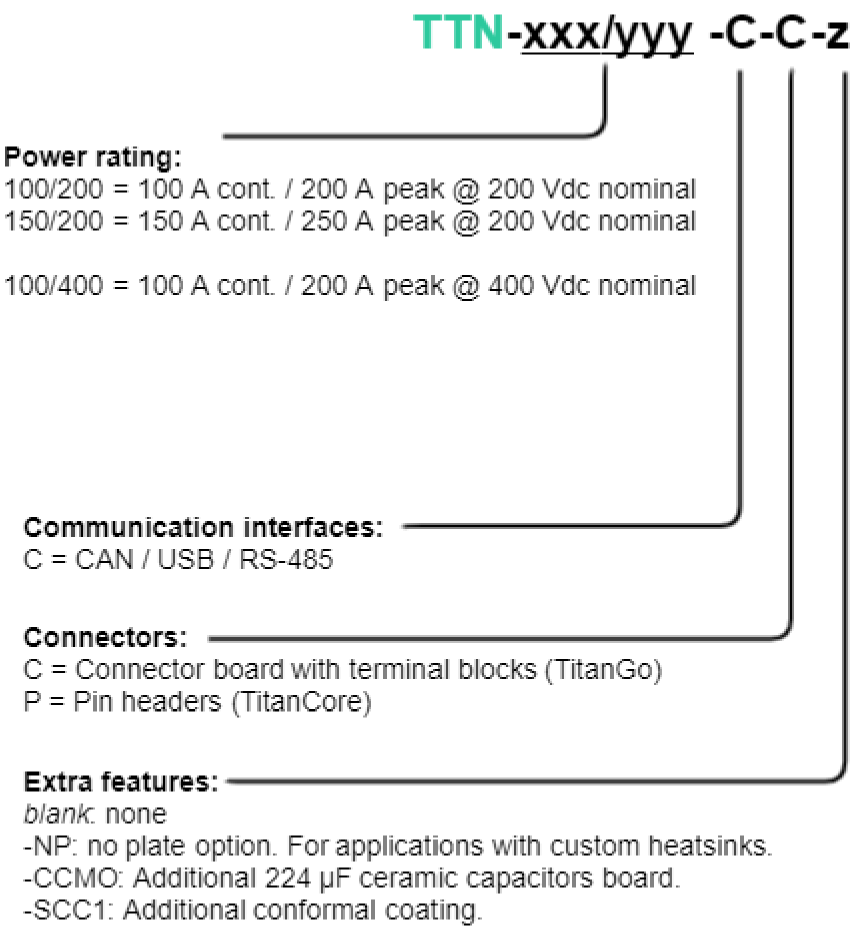
4 Product Description

The Titan Go Servo Drive is a high power density solution providing top performance, advanced networking and built-in hardware and firmware based safety, as well as a fully-featured motion controller. It can control multiple motor types and supports almost any feedback sensor including absolute serial encoders and resolvers.

Its design includes multiple communication ports as CANopen, RS-485, USB all of them are electrically isolated.

The Titan Go Servo Drive has been designed with efficiency in mind. It incorporates cutting-edge power semiconductor technology as well as optimized control algorithms to provide the perfect trade-off between electromagnetic emissions and performance.

4.1 Titan part numbering



Ordering part number	Status	Image
TTN-150/200-C-C-CCMO	PRODUCTION	-
TTN-100/400	OBSOLETE	-

Specifications

A list of features of the Titan Go Servo Drive is shown next.

Electrical and power specifications		
Part number →	**TTN-150/200**	**TTN-100/400**
Power supply voltage	10 V_{DC} to 200 V_{DC}	10 V_{DC} to 400 V_{DC}
Auxiliary logic supply input voltage range	10 V_{DC} to 65 V_{DC}	
Standby logic supply consumption	≤ 10 W	
Transient peak voltage	220 V_{DC}	450 V_{DC}
DC bus capacitance	63 µF (+224 µF if CCMO version is chosen)	
Minimum motor inductance	50 µH (for low inductance motors use high PWM frequency mode)	50 µH
Nominal phase continuous current (BLDC mode)	150 A_{RMS} (with heatsink)	65 A_{RMS} (with heatsink)
Nominal phase continuous current (DC mode)	150 A_{DC}	65 A_{DC}
Maximum phase peak current	250 A_{DC} (1 s)	85 A_{DC} (1 s)
Current sense range	± 457 A (Versions 1.0.0 and 1.1.0) ± 359 A (Version 1.2.0)	
Current sense resolution	893 mA/count (Versions 1.0.0 and 1.1.0)	
	701.8 mA/count (Version 1.2.0)	
Shunt braking transistor	Low side shunt braking transistor on board. 100 A continuous braking current capacity.	

Inrush current	< 10 A at connection. Titan includes a 2 kΩ DC bus capacitor precharge resistor that limits the inrush. No need for external capacitor precharge circuits or relays.
Cold plate	7 mm aluminum plate 6082-T6.
Power connectors	Power ring terminals with M8 screws and washers included. **The maximum absolute screw torque is 9 Nm.** Do not exceed 9 Nm in any axis to the power connectors, take care of bus bars and thick motor cables.
Efficiency	>97% at the rated power and current. Note that the 400 V 100 A version is more efficient at low load, while the 200 A version is efficient at high load.
Motion control specifications	
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	10 kHz (default) 20 kHz (alternative PWM frequency, configurable, preferred for low inductance motors)
Current sensing	Isolated current sense on phases A, B, and C. Accuracy is ± 2% full scale. 10 bit ADC resolution.
Sensors for commutation (brushless motors)	• Digital Halls (Trapezoidal) • Digital Quadrature encoder (Sinusoidal / Trapezoidal) • PWM encoder (Sinusoidal / Trapezoidal) • Analog potentiometer (Sinusoidal / Trapezoidal) • Resolver (Sinusoidal) • Sensorless Mode (Sinusoidal) • Sin/Cos encoder (Sinusoidal). (from version 1.2.0) • Absolute encoder SSI (Sinusoidal / Trapezoidal) ⓘ It is recommended to install the SSI only firmware variant if absolute encoder SSI is used for commutation.
Sensors for servo loops	• Digital Halls • Digital Quadrature encoder • Absolute encoder (SSI) • PWM encoder • Analog potentiometer

	• DC tachometer • Resolver • Sin/Cos encoder (from version 1.2.0)
Supported target sources	• Network communication – USB (for configuration or in-house updates, USB is not recommended for operation in field as it is a weak interface in high power - high noise environments) • Network communication – CANopen • Network communication – RS-485 • Standalone (execution from internal EEPROM memory) • Analog inputs • Step and Direction (Pulse and Direction) • PWM command • Encoder Following / Electronic Gearing
Resolver specifications	• Excitation voltage: Pure sine wave 3.8 V_{rms} 10.8 $V_{p\text{-}p}$. It can work with higher voltage rated resolvers as well. • Excitation frequency: 10 kHz • Resolver gain (transformation ratio): 0.5 ± 20% (default). Any other on demand. Contact Ingenia. • Input differential resistance ~ 24 kΩ
Inputs/outputs and protections	
General purpose Inputs and outputs	• 5 x isolated single-ended digital inputs. GPI1, GPI2, GPI3, HS_GPI1, HS_GPI2 (5 V TTL logic) • 1 x isolated (±10 V) differential analog input (12 bits). AN_IN1 • 1 x isolated digital output. GPO1 (3.3V logic)
Dedicated Inputs and outputs	• 2 x isolated Safe Torque Off inputs (24V level). • 1 x isolated Safe Torque Off status feedback optocoupler output. • 1 x motor temperature sensing input
Output Supplies	• 1 x 5 V output supply for powering external circuitry (up to 200 mA). Short circuit protected, ±2% tolerance. • 1 x 24 V output supply for external circuitry such as fans, relays or STO (up to 400 mA). ±25% unregulated tolerance. Not short-circuit protected.

Protections	• User-configurable:
	    • DC bus over-voltage
	    • DC bus under-voltage
	    • Drive over-temperature
	    • Drive under-temperature
	    • Over-current
	    • Overload (I^2t)
	• Short-circuit protections:
	    • Phase to SUP+
	    • Phase to SUP-
	    • Phase to phase
	    • Phase to Earth

	• 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 • Can drive an external power braking resistor in case of re-injection
Safe Torque Off	2 x STO inputs, 24 V isolated inputs (work from 15 V to 30 V). Redundant topology with self-test features. Ready for SIL 3 reliability level but not certified. 1 x STO feedback indication output for external self-verification circuit. Minimum pulse width for Safe Torque Off activation (and power stage shutdown): 14 ms Minimum pulse width for STO feedback reaction: 1 ms. Pulses < 1 ms can be used for safety PLCs but will be ignored. Pulses between 14 ms and 1 ms can be used for self test.
Motor Brake	Not available.
Communications	
USB	MiniUSB (2.0) vertical connector. Fully isolated 2.5 kV_{RMS} 1 min.
Serial	RS-485 full-duplex (compatible with RS-422) isolated 2.5 kV_{RMS}. Default 115200 bps, 8 data bits, no parity, 1 stop bit, no flux control. 120 Ω terminations for TX and RX included on board with DIP switches. TX+ and RX+ biased to +5 V with 4.7 kΩ. TX- and RX- biased to GND with 4.7 kΩ.
CANopen	CANopen compliant with isolation (self powered, no need for external supply). 1 Mbps max (default). 120 Ω termination included on board with a DIP switch. CiA-301, CiA-303, CiA-305, CiA-306 and CiA-402 compliant.
EtherCAT	-
Environmental and mechanical specifications	
Part number →	
Cold plate temperature	• -40ºC to +85ºC full current (with appropriate heatsink) • +85ºC to 110ºC derated current.

Heat dissipation	The maximum heat dissipation is 4 kW. Provide a heatsink according to environment temperature and power rating. Heat dissipation is affected mainly by the phase current and voltage. In order to achieve the maximum power ratings, **excellent heat transfer is needed between the cold plate and a heatsink**. Please see Dimensions and assembly for details.
Maximum humidity	5% - 85% (non-condensing). Titan can be supplied with conformal coating.
Horizontal dimensions	206 x 172 mm
Maximum height	55 mm
Weight (exc. mating connectors)	1878 grams

4.2 Hardware revisions

Hardware revision	Individual board references	Description and changes
1.0.0 May 2017	i047-01H1-1.0.0 i047-01H2-1.0.0 i047-01H3-1.0.0	First product beta release.
1.1.0 September 2017	i047-01H1-1.1.0 i047-01H2-1.1.0 i047-01H3-1.1.0	First product release. Changes from the previous version: • Modifications on the aluminum cooling plate, reduction of 1 mm thickness and added extra PCB support area for better vibration and thermal performance. • Added 2.5 kV isolation to USB ports. The drive is no longer powered from USB but communication reliability is greatly enhanced. • Change high voltage notification LED to blue for better visibility. • Enabled the main DC/DC converter that is powered from the DC bus. Auxiliary 24V power supply input becomes optional. • Improved protections for the 24V output supply. • Added 24V bus monitoring. • Added motor temperature sensing input. • Added pre-biasing resistors 4.7 kΩ to the RS485 lines. Pull up to 5 V for positive GND for negative. • Modified HALLs circuit with galvanic isolation. • Manufacturing PCA improvements. • Added mechanical stress relief slots on the power board. • Added electrical creepage slots on the control board. • Modified version TTN-200/400 with IGBTs to improve performance at high load.

Hardware revision	Individual board references	Description and changes
		• Improved creepage distances on the power stage. • Changed PCB finishes to unify black aspect on all boards and increase radiation heat dissipation at high altitude. • Modified PCB design for with IPC class 3/A. High-reliability aerospace requirements. • Changed shunt recirculation diode. • Modified STO circuit for SIL3 compliance. Increased minimum pulse time to 20 ms to allow self-test functions. • Improve the thermal performance of some internal power supplies. • Solved CAN hardware blocking bug. • Increased DC bus capacitance on all variants.
1.2.0 January 2018	i047-01H1-1.2.0 i047-01H2-1.2.0 i047-01H3-1.2.0	Improvements in current sensing and EMI at high current performance. • **Improved current sense resolution** to allow better torque control. From 893.0 mA/count to 701.8 mA/count on version 1.2.0. • Added Safe Torque Off **(STO) bypass jumpers**. • Added **Sin/Cos encoder** compatibility. • **Separated the Incremental encoder from the Absolute encoder connectors.** The pinout is still 100% compatible with wirings of version 1.1.0. • Added power terminals plastic insulator and stiffener to make connections more robust. • Improved EMI USB robustness. This allows for operation at high power even with USB connected. • Removed Safe Torque Off error at power-up that caused the reset. • Improvement of overcurrent performance. • Improvement on EMI of the power stage. • Manufacturing improvements.

Identifying the hardware revision

Hardware revision is screen printed on the board. It can also be read from Motion Lab - Drive parameters.

4.3 Power and current ratings

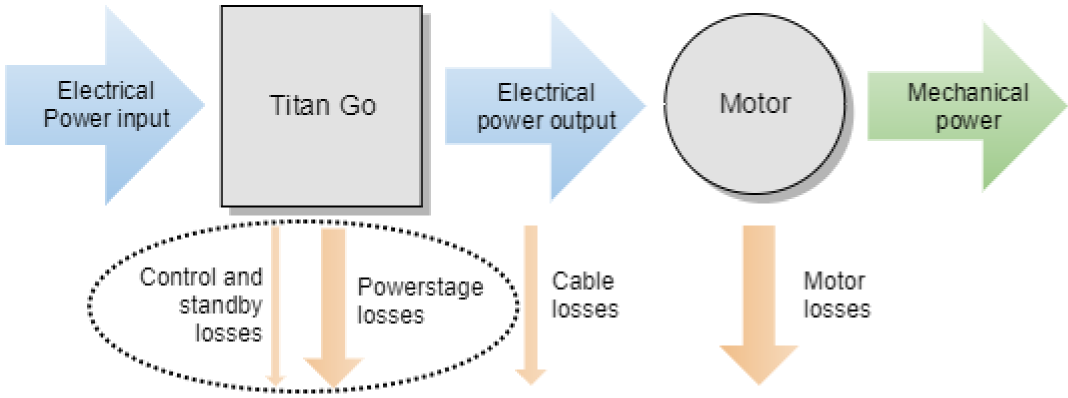
TTN-x/xx-C-C variants of Titan Go are capable of providing the nominal current from -40 ºC to 85 ºC (temperature measured in the cold plate) with a 0.1 ºC/W heatsink (Fischer LA 11 200 24) attached by means of a low thermal resistance interface material. Above 85 ºC a current derating could be needed to prevent overheating. Above 85 ºC a current derating could be needed to prevent overheating. Please see Dimensions and assembly for further details.

In case of excessive power losses, over-temperature will be detected, causing the driver to turn off. The system temperature is available in E-Core registers and is measured near the power stage. This temperature parameter can be accessed from USB 2.0, CAN or RS485 serial interface and does not indicate the air temperature, but the temperature of the PCB. Above 110 ºC the Titan Go automatically turns off the power stage and stays in fault state avoiding any damage to the drive. The Fault LED will be activated and latched until the temperature decreases below this threshold.

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

Some parts of the Titan Go can exceed 125 °C during operation, especially at high load levels.
Do not touch the Titan Go during operation and wait at least 5 minutes after turn off to allow a safe cool down.

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



4.3.1 Power losses calculation (heat dissipation)

Current flowing through Titan Servo Drive causes power losses that, ultimately, are converted in heat. This heat must be transferred to its surrounding environment efficiently so that the temperature of the drive does not reach dangerous levels. The greater the power losses, the more effective the heat dissipation must be. Power losses mainly depend mainly on 3 parameters:

- **Motor RMS current**: this is the cause of what is called *static* or *conduction* power losses, which typically are the main source of power losses, having that they show a positive correlation in a squared ratio.
- **DC bus voltage**: this, along with the motor RMS current and PWM switching frequency, is the cause of what are called *dynamic* or *commutation* losses, and show positive correlation in a proportional ratio.
- **PWM switching frequency:** similar to DC bus voltage, the PWM switching frequency directly affects the commutation losses. Typically, 10 kHz is the default value to reduce these losses, but it can be increased up to 20 kHz.

PWM switching frequency and nominal specifications

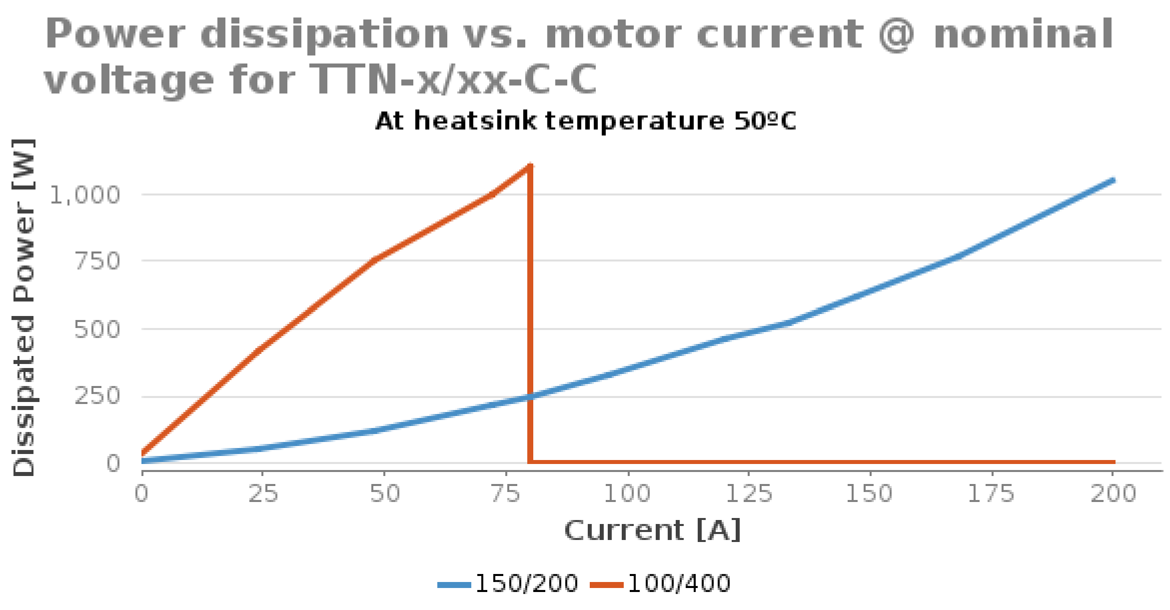
All nominal specifications in this manual are measured under a PWM switching frequency of 10 kHz.

PWM in SMO feedback mode

It is strongly recommended to configure the alternative PWM frequency of 20 kHz when using the sensorless SMO as a feedback source, or when controlling motors of low inductance.

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

- Air temperature: higher power semiconductor temperatures reduce their efficiency.
- Motor speed: faster motor speeds result in higher overall power losses since the input DC bus current is greater, and this increases conduction losses on the reverse polarity protection circuitry.



4.3.2 Current ratings

Power losses cause the drive to increase its temperature according to:

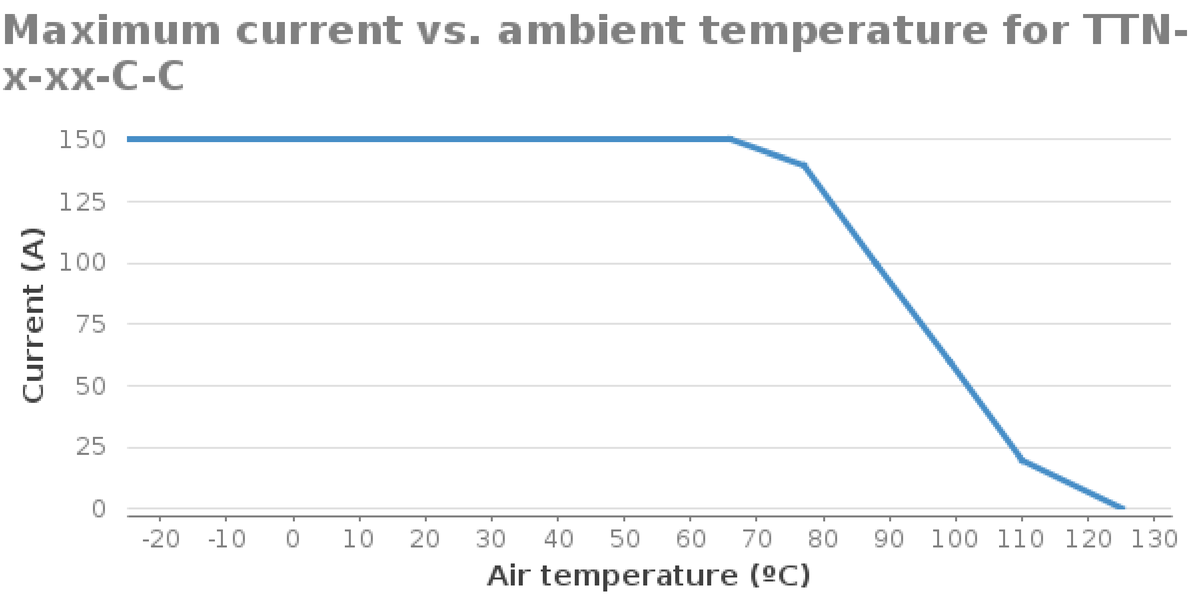
$$T_P \approx T_A + P_{LOSS} \cdot Z_{\theta PA}$$

As power losses have a positive correlation with the motor RMS current, 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 mainly depends on the DC bus voltage.

Parameter	**Valu e**	**Unit s**	**Notes**
Maximum absolute power stage temperature	110	°C	Measured on the PCB (not the heatsink) and accessible via register.
Thermal resistance from power stage to the heatsink	0.01 7	°C/W	Does not consider the thermal resistance of the heatsink, but assumes the cold plate is a thermal conductor, not the thermal dissipator.
Thermal resistance from power stage to air	5	°C/W	Considering the drive is vertical and free air convection with is allowed on the cold plate surface (> 30 cm clearance around the drive). Mounting the drive without heatsink could only be done for very low load applications or debugging purposes, otherwise, over-temperature alarm will occur after a few minutes of operation.

Parameter	Value	Units	Notes
Temperature stabilization time	800	s	With 0.1 °C/W heatsink attached. Considering 90 % of the maximum temperature.

This graphic shows the maximum current with respect to ambient temperature, also assuming a 0.1 °C/W heatsink attached.

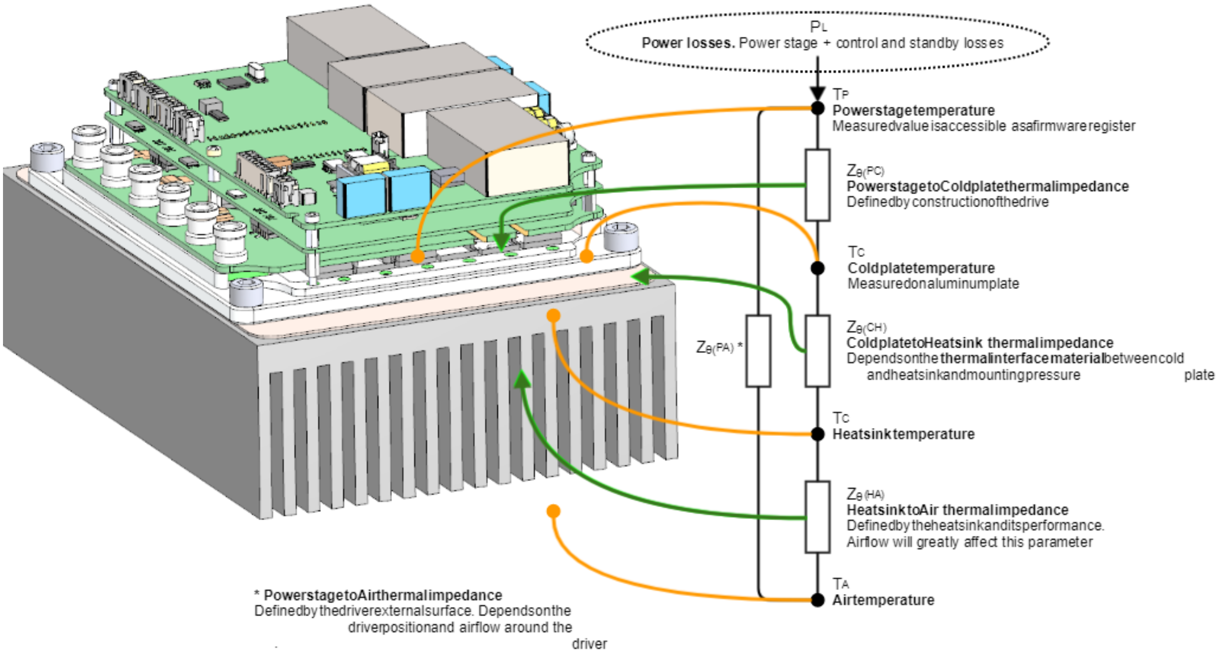


> **Current derating**
>
> The current derating graph is only indicative and is based on thermal tests performed in a climatic chamber where there was enough room for natural air convection. Each application may reach different ratings depending on the installation, ventilation and/or housing.
> Current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

4.3.3 Maximizing heat dissipation with a heatsink

A heatsink is needed to reach the nominal current at any ambient temperatures. When using high-efficiency heatsinks or in enclosed spaces, the equation can be simplified as follows.

$$T_P \approx T_A + P_{LOSS} \cdot (Z_{\theta PC} + Z_{\theta CH} + Z_{\theta HA})$$

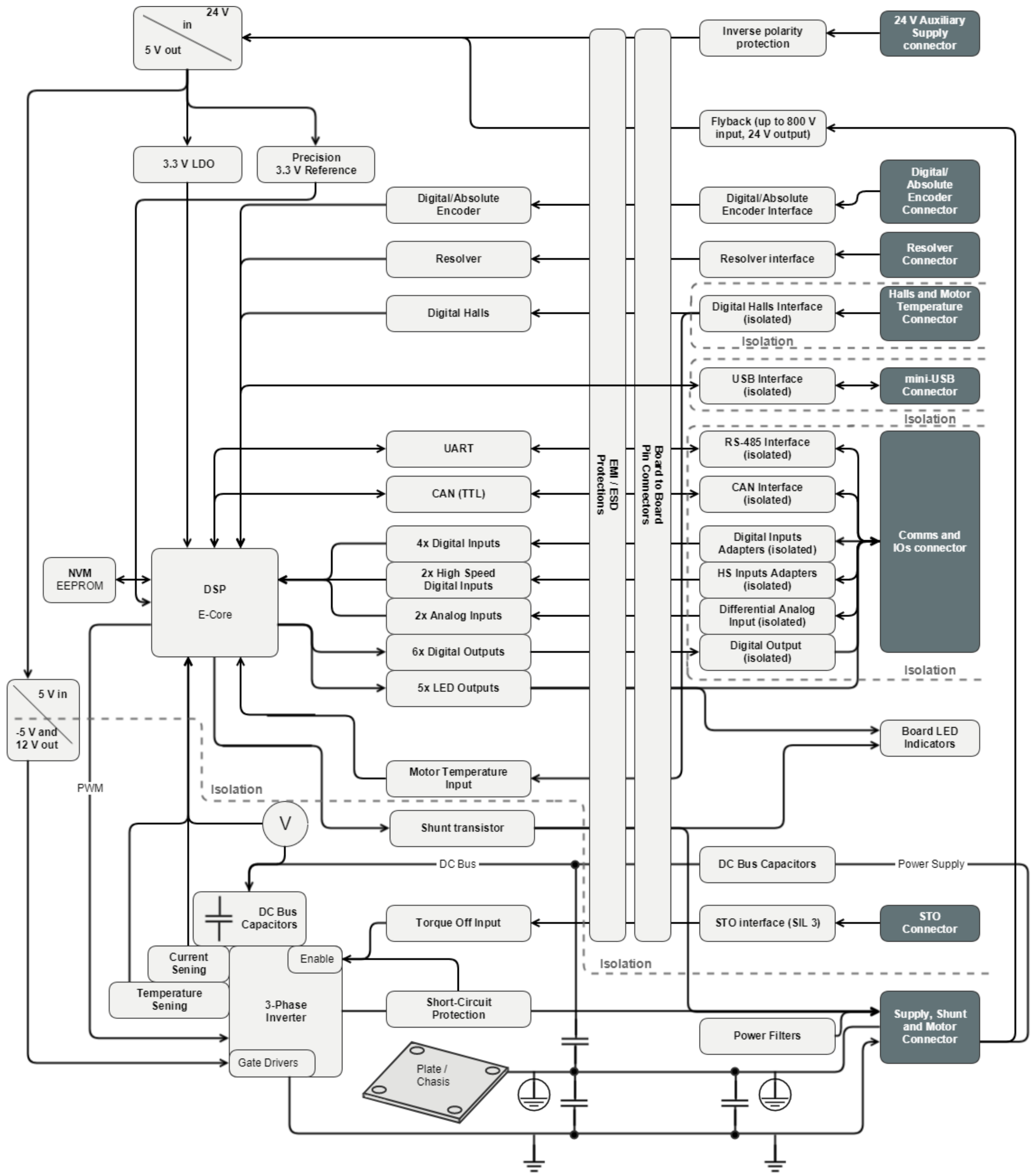


Assembly recommendations for best heat dissipation

- Always allow natural air convection by ensuring ≥ 10 mm air space around the drive.
- Use a good thermal interface material to improve the heat dissipation. See Dimensions and assembly for details.
- If housed, use a good thermal conductivity material, such as black anodized aluminum. Placing the drive in a small plastic package will definitively reduce its temperature range.
- Temperature range can be increased by providing forced cooling with a fan. **Always ensure electrical isolation between live parts and the heatsink**.

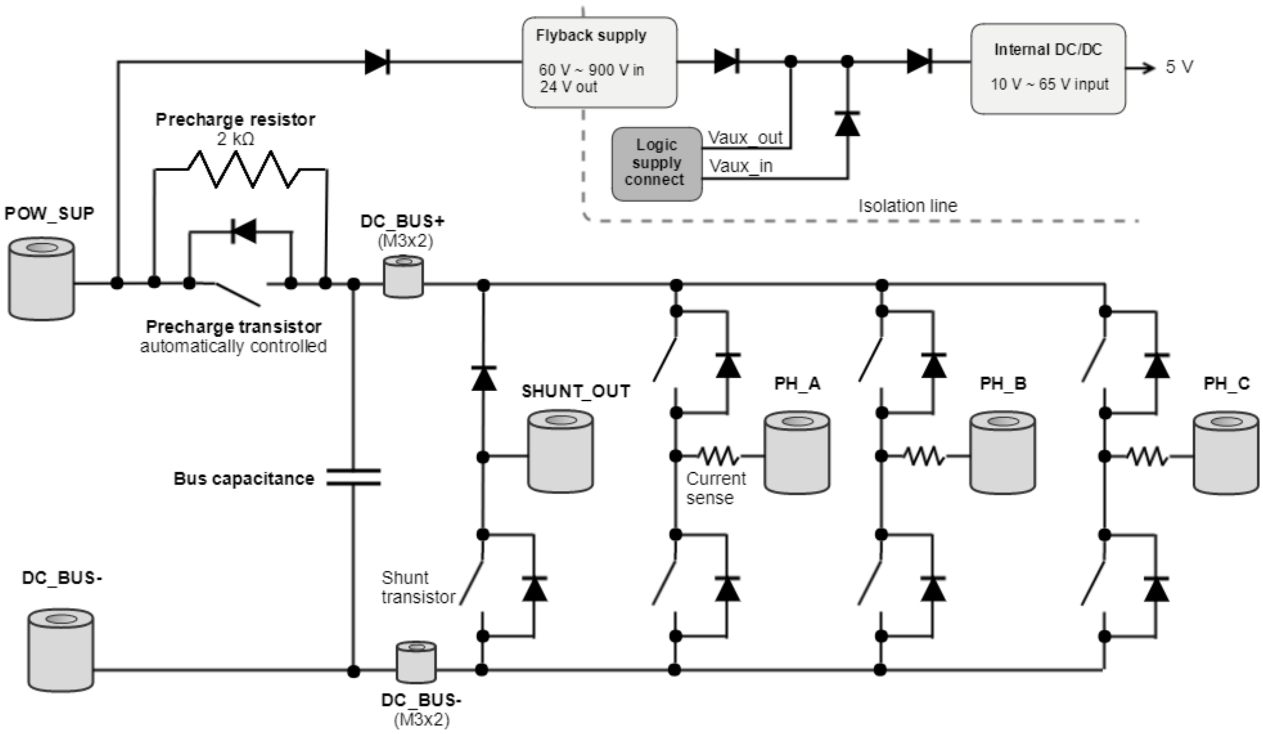
4.4 Architecture

This diagram represents the main hardware elements of Titan Go, and how they relate to each other.



4.4.1 Power stage and supply architecture

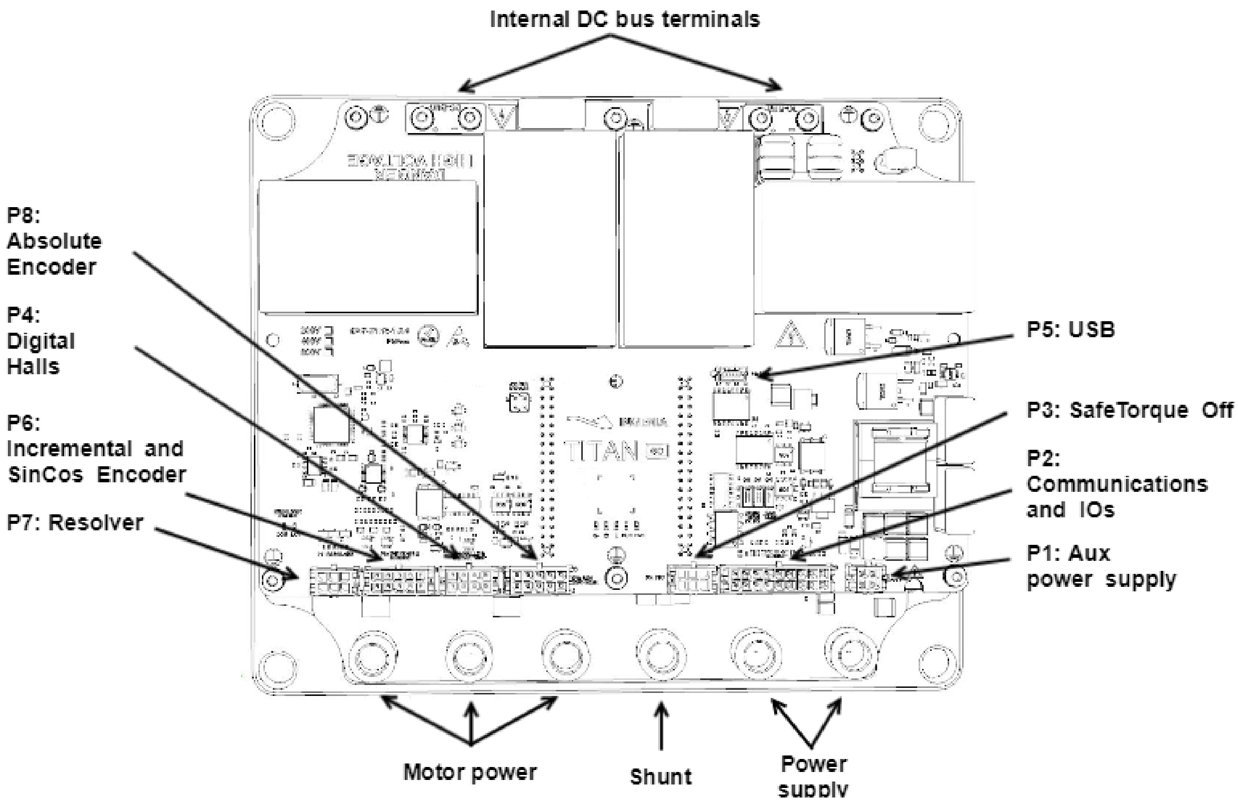
The following drawing shows the architecture of the power stage and its main components. Also, it clarifies how the internal power supplies are wired. For simplicity, power transistors are shown as switches.



Note: Transistors are represented as switches for simplicity. In reality they are various MOSFETs (200V) and IGBTs (400V) in parallel for each switch.

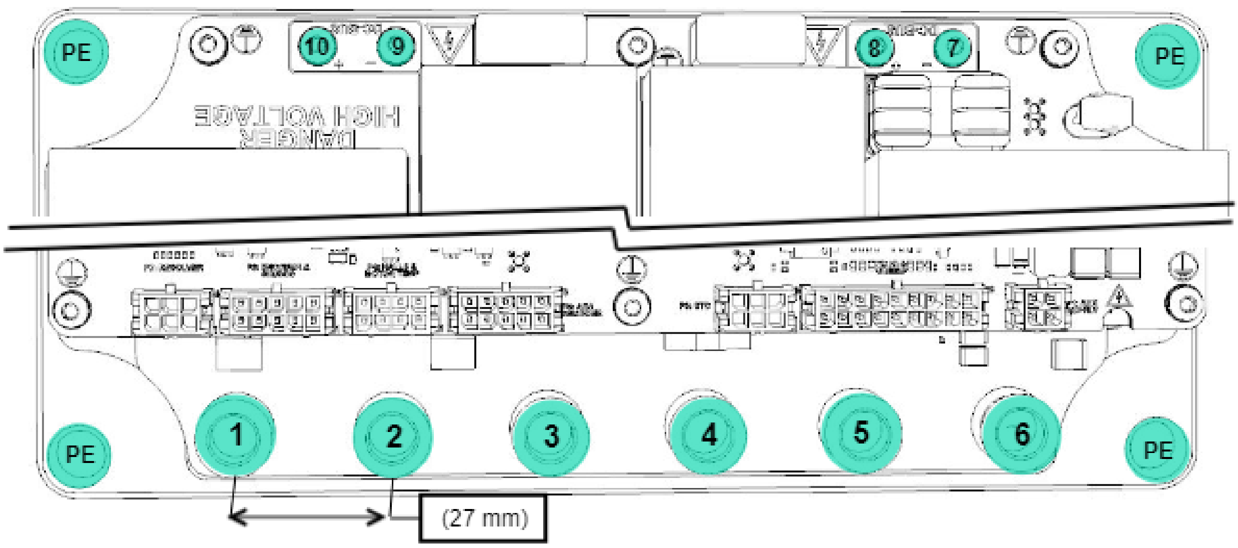
5 Connectors Guide

This chapter details the Titan Go Servo Drive connectors and pinout.



5.1 Supply, shunt and motor terminals

Power terminals



1 to 6: M8 female terminal, 27 mm pitch. ERNI 225872. 7 to 10: M3 torx screw terminal. PE holes: 9 mm diameter.

Pin	Signal	Function	Screw size
1	PH_C	Motor phase C (Do not connect for DC and voice coils)	M8
2	PH_B	Motor phase B (Negative for DC and voice coils)	
3	PH_A	Motor phase a (Positive for DC and voice coils)	
4	SHUNT_OUT	Shunt braking transistor output (Shunt braking resistor should be connected between +POW_SUP and SHUNT_OUT)	
5	GND_P	Power ground connection (Isolated from logic GND and Protective Earth)	
6	POW_SUP	Power supply positive	
7, 9	DC_BUS-	Internal DC bus negative. Internally connected to GND_P but not intended as power supply terminal. Used for additional DC link capacitance.	M3
8, 10	DC_BUS+	Internal DC bus positive. Not intended as power supply terminal. Used for additional DC link capacitance. Titan includes an internal capacitor soft precharge circuit, removing the need for external precharge relays.	

Plate	PE	Protective Earth. The assembly screws must be used as earthing connectors.	M8
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 20 mm² ~ 33.5 mm² • Never exceed the 9 Nm screw limit for the power connectors as this could cause permanent damage. • The torque generated by the cables or bus bars must never exceed 9 Nm in any axis. Take care to fasten the cables or bus bars to prevent unnecessary forces.			

Extra capacitance

It is recommended to add extra capacitance to the main DC supply. The Titan Go has minimal DC bus capacitance that is enough to filter high frequency currents and is enough for battery powered applications. However it could not be enough in some cases and could damage the power supply by demanding excessive current ripple. Add at least a total capacitance of 5 µF/ A (motor phase RMS) to avoid stressing the power supply and minimize EMI problems. Use good quality DC link metalized polymer film capacitors with low ESR (suggested polypropylene).

5.2 Ring terminals and screws

Due to the high current ratings, ring terminals and screws are needed for the power terrminals. Following are shown the recommended part numbers.

M8 screw		**Assembly**
Description	M8 allen screw, 12 mm length	**Maximum torque** The maximum torque applied to the screws **must never exceed 9 Nm**. It can damage the connector and also the printed circuit board. The following picture shows the correct order of the mechanical elements and extra comments for the assembly.

M8 screw		**Assembly**
Part number	RS-Pro232-8322	
Distributor codes	RS 232-8322	
Crinkle washer		
Description	M8 stainless steel crinkle washer	
Part number	Duratool D00829	
Distributor codes	Farnell 1614006	
Ring terminal		
Description	M8 insulated ring terminal, 2 AWG cable	
Part number	Molex 0190710285	
Distributor codes	Digi-Key WM13727-ND Mouser 538-19071-0285	
Brass washer		
Description	M8 brass washer	
Part number	RS-Pro 483-2637	
Distributor codes	RS 483-2637	

5.3 Micro Fit 3.0 connectors mating

All Titan Go Servo Drive signal and communication connections are based in Molex Micro-Fit™ 3 mm pitch connectors. Multi-core crimped cables can be used for wiring inputs, outputs, feedbacks and communications.

Multi-core crimped cable mating	
Description	Molex Micro-Fit™ Receptacle Housing, 3.00mm Pitch.

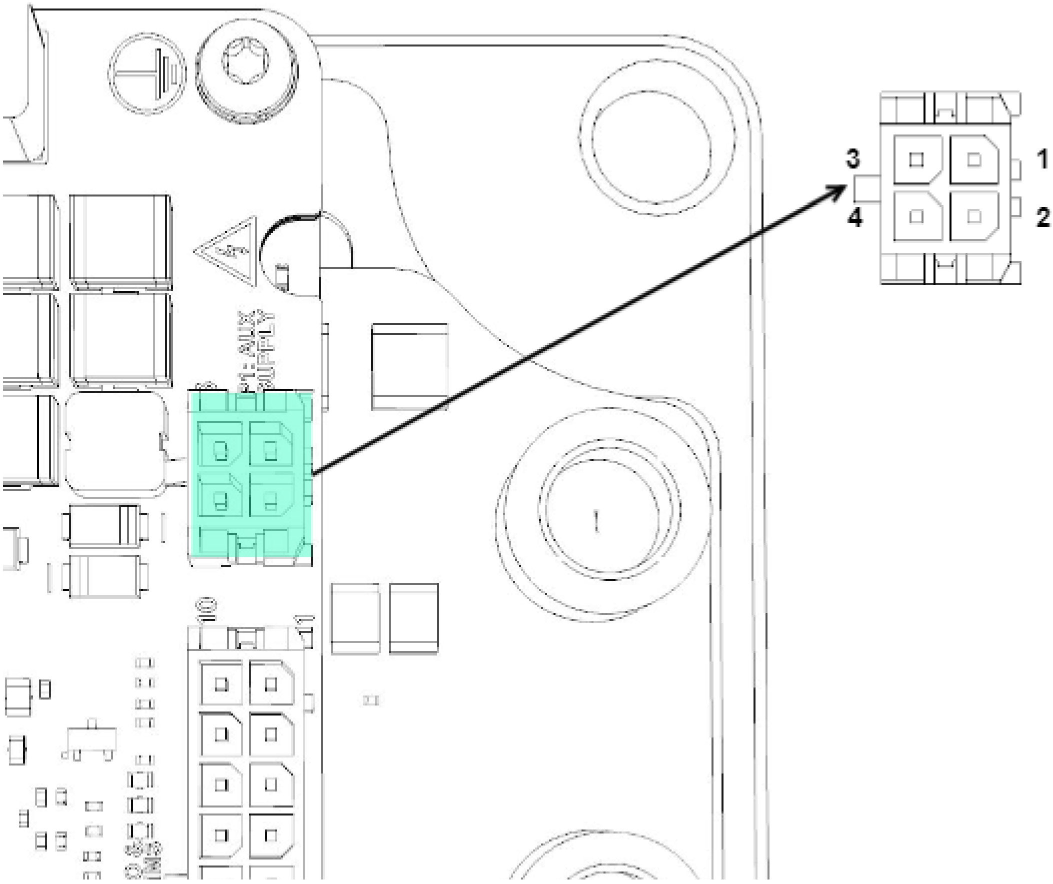
Multi-core crimped cable mating	
Image	
Crimp terminals	
Description	Micro-Fit™ Crimp Terminal, Female, Tin, Lead free
Image	
Part number	Molex 43030-0001
Distributor codes	Farnell 1462526 / Digi-Key WM1837CT-ND / Mouser 538-43030-0001-CT
Pre-assembled wires	
Description	20-24 AWG pre-crimped jumper cable (50.8 mm). Note: there are many lengths and colors available at Digi-Key.
Image	

5.4 P1: Aux supply connector

Titan GO is self supplied from the DC bus using an internal DC/DC converter that starts at 60 V and works up to 850 V.

However, some applications require an independent auxiliary power supply to work with the power off. This can be done with connector P1.

This connector also includes a +24 V output that can be used for fans, relays or for STO circuits.

P1 connector		
 4 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header. Molex		
Pin	**Signal**	**Function**
1	GND_D	Logic ground connection, isolated from GND_P
2	+24V_IN	+24 V logic supply input (10 V to 60 V)
3	GND_D	Logic ground connection, isolated from GND_P
4	+24V_OUT	+24 V logic auxiliar supply output

Notes

- The internal logic supply can be monitored using the analog input 2.

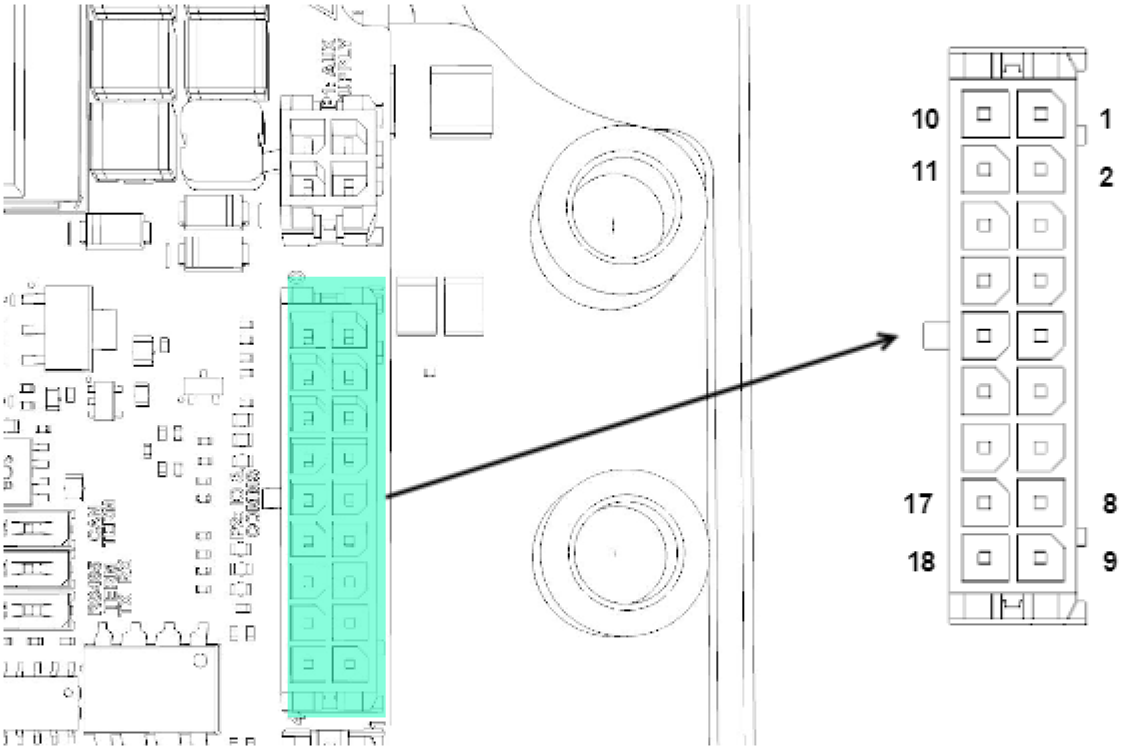
> MOLEX Micro-Fit connectors do not follow the typical pinout layout of other connectors such as pin headers or ribbon connectors.
> Pay close attention not to connect them in a wrong order.

P1 Mating	
Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 4 Circuits.
Image	
Part number	Molex 43025-0400
Distributor code	Digi-Key WM1784-ND / Mouser 538-43025-0400 / Farnell 672890
Notes	
• See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.	

5.5 P2: Communications and IOs connector

Titan GO has an isolated connector for the communications and the inputs/outputs. It includes RS-485, CAN, 5x Digital inputs, 1x Digital output and 1x Analog input.

P2 connector



18 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header.

Pin	Signal	Function
1	RS485_RX+	RS485 receive data + (should be connected to master TX+)
2	RS485_RX-	RS485 receive data - (should be connected to master TX-)
3	CAN_L	CAN bus line dominant low
4	CAN_H	CAN bus line dominant high
5	GND_ISO	Ground for the isolated connector
6	AN_IN+	Differential ±10 V analog non inverting input Single ended analog input
7	GPI2	General purpose single ended digital input 2
8	+5V_ISO	5 V 50 mA max
9	GND_ISO	Ground for the isolated connector

10	RS485_TX+	RS485 transmit data + (should be connected to master RX+)
11	RS485_TX-	RS485 transmit data - (should be connected to master RX-)
12	GND_ISO	Ground for the isolated connector
13	GPO1	General purpose digital output
14	GPI1	General purpose single ended digital input 1
15	AN_IN-	Differential ±10 V analog inverting input Single ended analog input ground
16	HS_GPI1	High speed digital single ended input 1 Command source: Pulse input Feedbacks: PWM input
17	GPI3	General purpose single ended digital input 3
18	HS_GPI2	High speed digital single ended input 2 Command source: Direction input
Notes		
• GPO1 is 0 to +3.3 V, with a 330 Ω resistor in series for current limiting.		

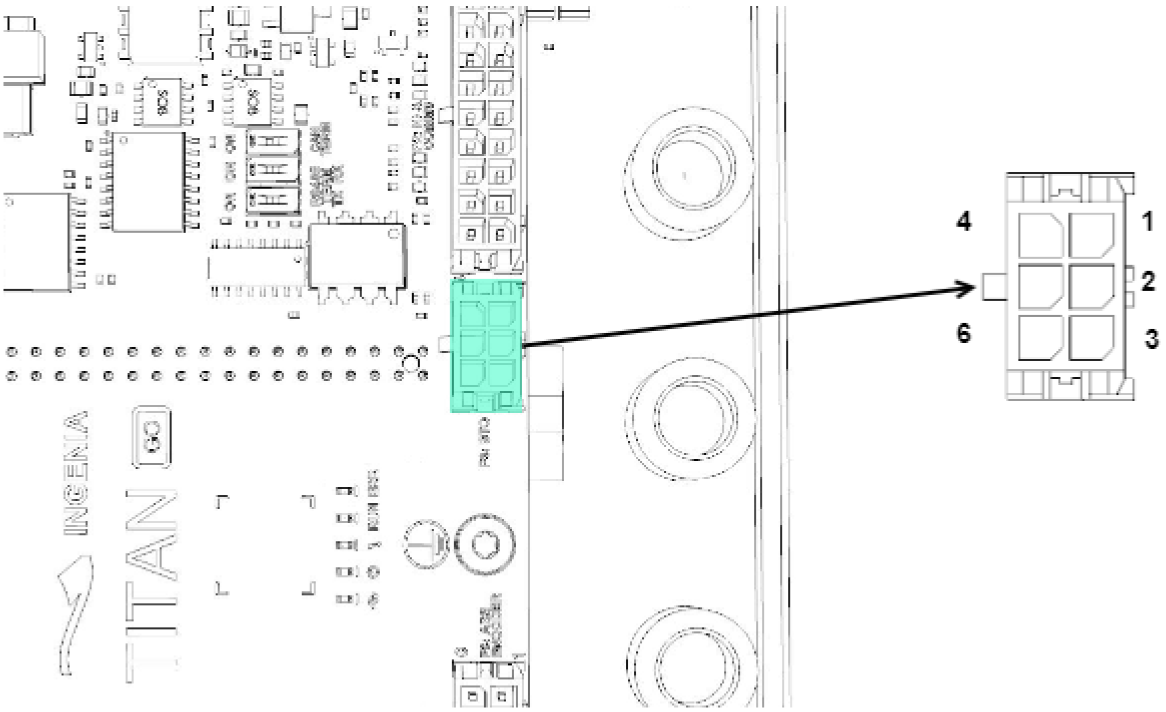
P2 Mating	
Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 18 Circuits.
Image	
Part number	Molex 43025-0400
Distributor code	Digi-Key WM2491-ND / Mouser 538-43025-1800 / Farnell 9961330
Notes	

- See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.

5.6 P3: Safe torque off connector

Titan GO has a Safe Torque Off interface (SIL 3 compliant).

P3 connector



6 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header. Molex

Pin	Signal	Function
1	STO1	Safe Torque Off input 1 (24 V levels)
2	STO2	Safe Torque Off input 2 (24 V levels)
3	STO_STATUS_EMITTER	Safe Torque Off Feedback output signalling optocoupler emitter
4	NC	Not connected
5	STO_COMMON	Safe Torque Off input common (optocoupler LEDs cathode).

6	STO_COLLECTOR	Safe Torque Off Feedback output signalling optocoupler collector

Notes

- In case you are not using STO functionality it must be bypassed. Connect STO_COMMON to GND of connector P1. Connect both STO1 and STO2 to 24V_OUT of connector P1.
- When STO is disconnected the power stage is totally disabled, including current sense amplifiers. It is not possible to read motor phase current with this error active.

P3 Mating	
Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 6 Circuits.
Image	
Part number	Molex 43025-0600
Distributor code	Digi-Key WM1785-ND / Mouser 538-43025-0600 / Farnell 672907

Notes

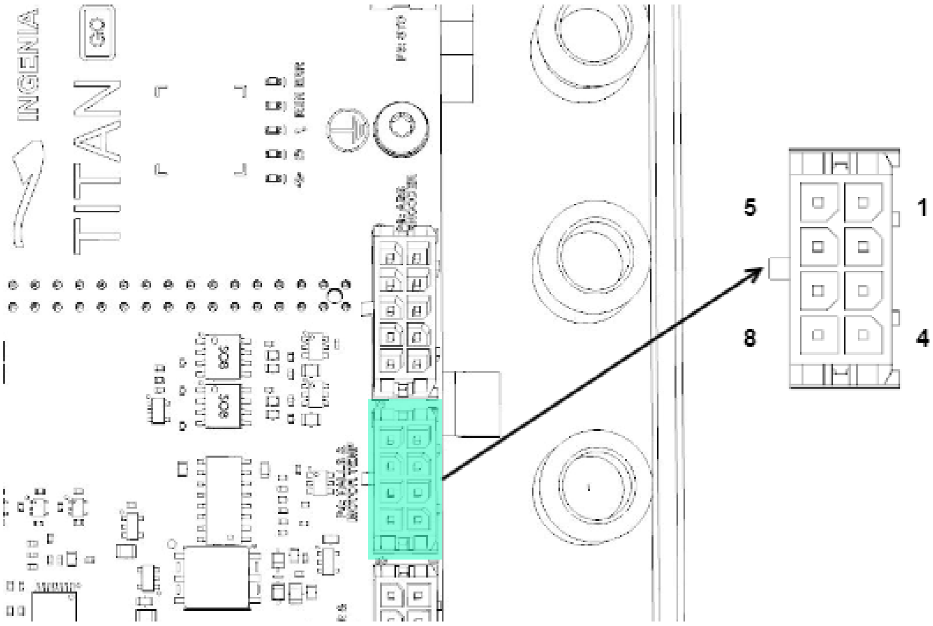
- See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.

5.7 P4: Digital halls and motor temperature connector

P4 connector

8 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header. Molex

Pin	Signal	Function
1	HALL_1	Digital Hall 1 sensor input
2	HALL_2	Digital Hall 2 sensor input

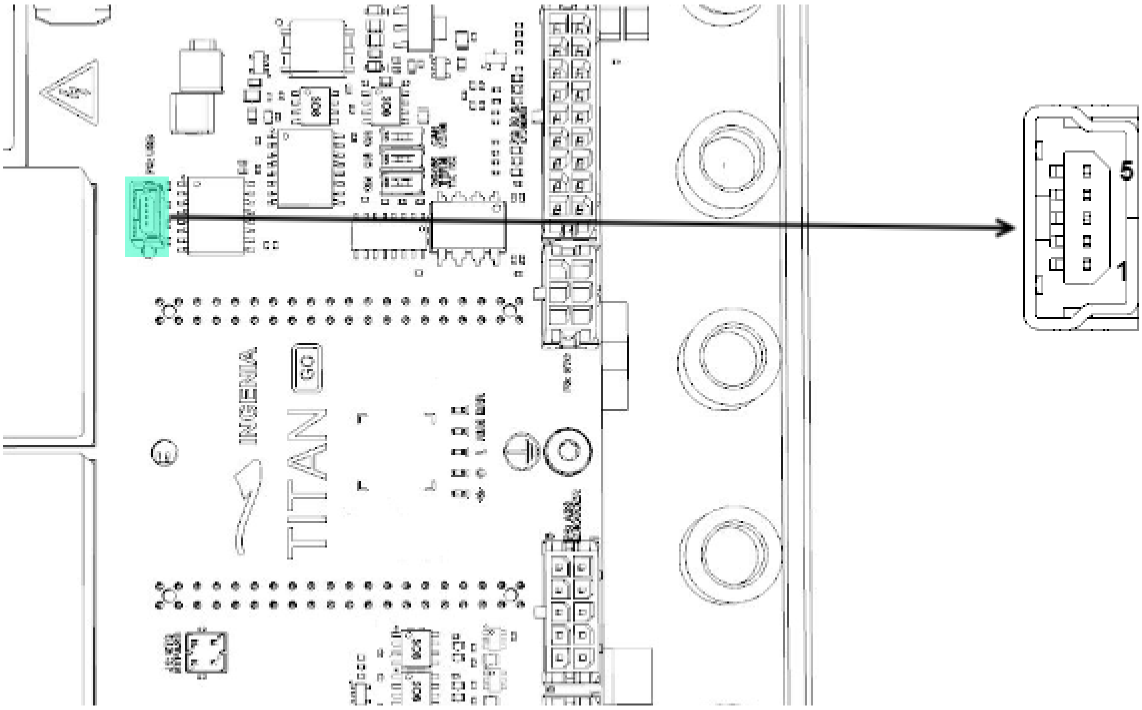
3	HALL_3	Digital Hall 3 sensor input
4	+5V_OUT	5 V 50 mA max isolated output for halls 
5, 6	GND_HALLS	Halls only ground connection, isolated from GND_P and GND_D to maximize noise immunity.
7	MOT_TEMP1	Motor temperature sensor connection (connect the other terminal to pin 8). Includes a 30 kΩ pull-up to 3.3 V. The pin is connected to analog input 3.
8	MOT_TEMP2	Motor temperature sensor return, a 330 Ω connects this pin to digital GND.
Notes		

P4 Mating	
Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 8 Circuits.
Image	

Part number	Molex 43025-0800
Distributor code	Digi-Key WM1786-ND / Mouser 538-43025-0800 / Farnell 672919
Notes	
• See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.	

5.8 P5: USB connector

P5 connector



5 pin vertical mini-USB connector. Wurth Electronics 651005136421.

Pin	Signal	Function
1	USB_SUPPLY	USB +5V. Does not supply the Titan.
2	USB_D+	USB Data+ line
3	USB_D-	USB Data- line
4	NC	Not connected

5	GND_USB	USB GND, isolated from all other GNDs.
SHIELD	NC	Connector metallic shield, NOT CONNECTED.

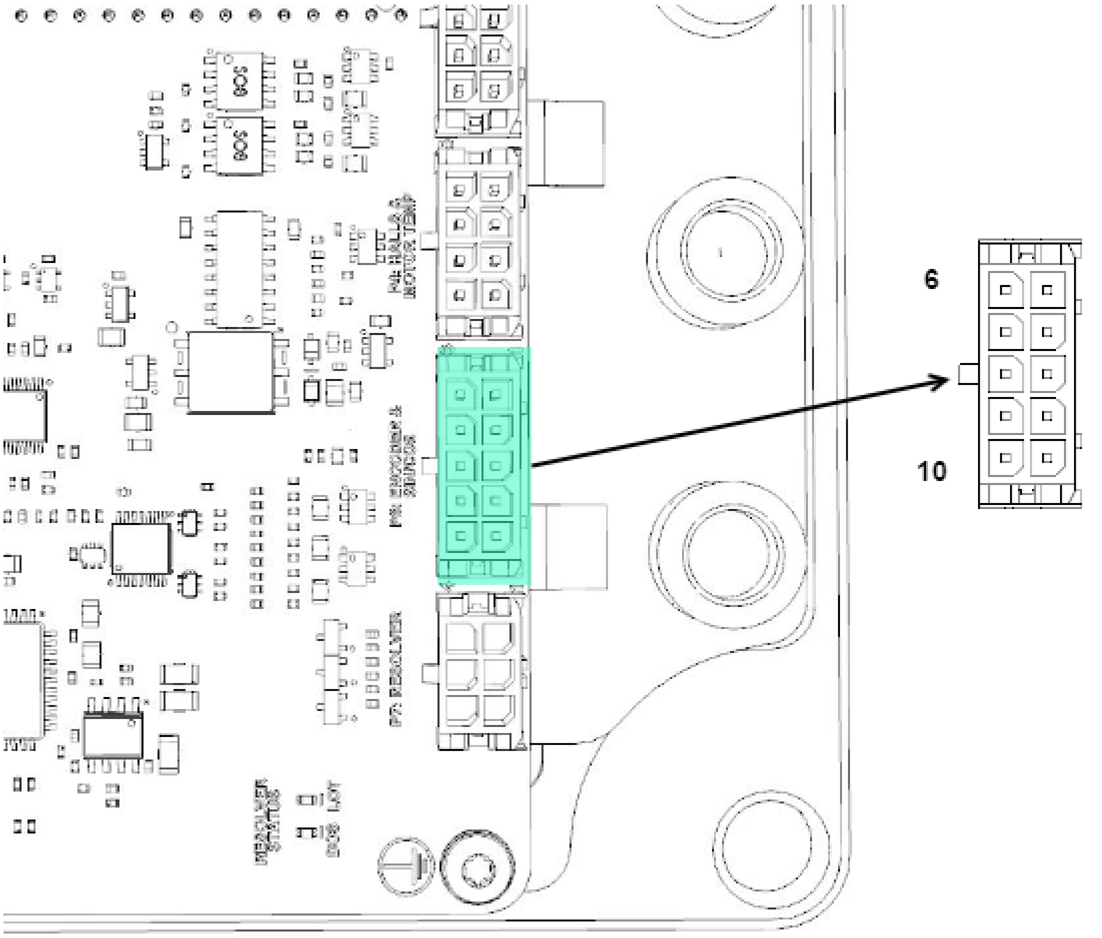
Notes

- **Avoid applying excessive lateral forces to the USB connector.**
- USB connection allows drive configuration using Motion Lab or downloading latest firmware revision.
- Shorter USB cables are preferred whenever possible for minimal EMI.
- Please see Communications page for further information.
- The Titan USB port is 100% isolated from the power.

P5 Mating	
Description	USB Shielded I/O Cable Assembly, USB A-to-Mini-USB B, 1 m Length, Black, Lead-Free. Not included in the delivery of Titan Go.
Image	
Part number	Molex 43025-0800
Distributor code	Digi-Key WM17493-ND / Mouser 538-88732-8602 / Farnell 1221071

5.9 P6: Encoder connector

P6 connector



10 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header. Molex.

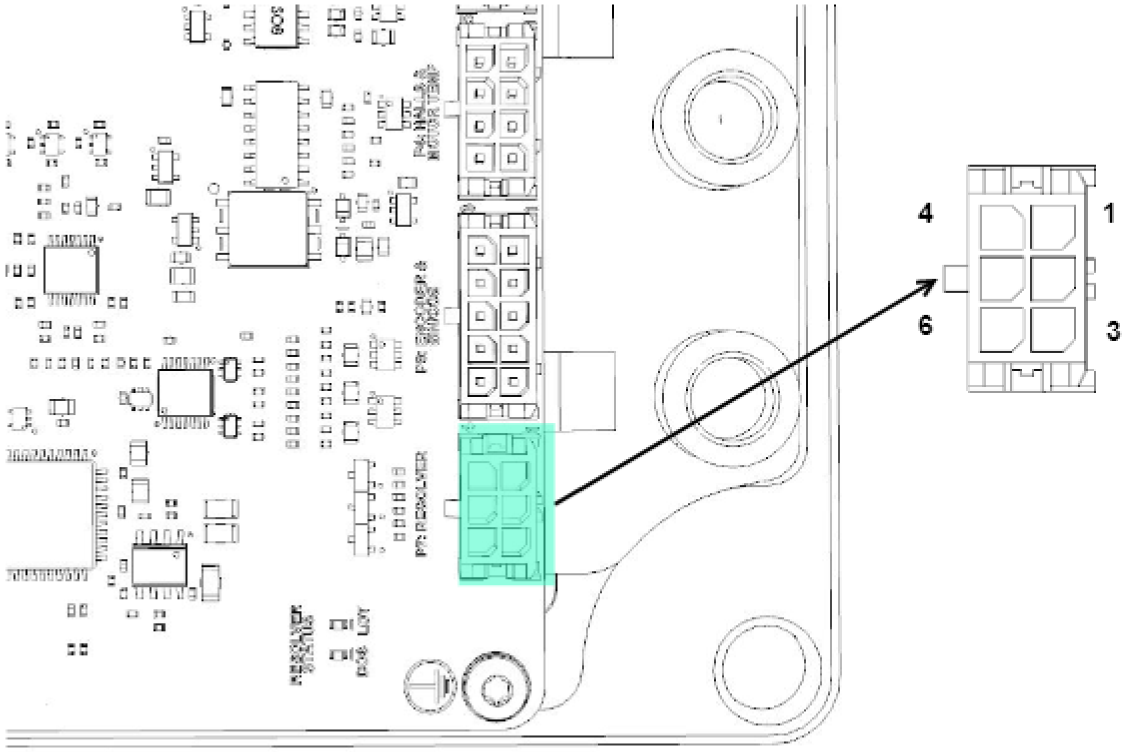
Pin	Signal	Function for incremental encoder	Function for analog encoder (Sin Cos)
1,3,8	GND_D	Logic ground.	
2	QEA/SIN_P	Quadrature A positive input	Sin positive input
4	QEB/COS_P	Quadrature B positive input	Cos positive input
5	QEZ/REF_P	Index positive input	Reference positive input
6	+5V_OUT	5 V 200 mA regulated and short-circuit protected power supply for the encoder	
7	QEA/SIN_N	Quadrature A negative input	Sin negative input
9	QEB/COS_N	Quadrature B negative input	Cos negative input

10	QEZ/REF_N	Index negative input	Reference negative input
Notes			
• Depending on the configuration by software, some pins can be inputs or outputs. Please, configure the encoder as incremental before doing connecting it to prevent signal collision between clock (output) and A signals (input)			

P6 Mating	
Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 10 Circuits.
Image	
Part number	Molex 43025-1000
Distributor code	Digi-Key WM1787-ND / Mouser 538-43025-1000 / Farnell 672920
Notes	
• See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.	

5.10 P7: Resolver

P7 connector



6 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header. Molex.

Pin	Signal	Function for incremental encoder
1	EXC+	Excitation positive
2	COS+	Cosine positive
3	SIN+	Sine positive
4	EXC-	Excitation negative
5	COS-	Cosine negative
6	SIN-	Sine negative

Notes

- Attention, this connector is the same model as the STO.
- Titan standard option is for resolver with a transform ratio of 1:0.5. Other gains are possible on demand.

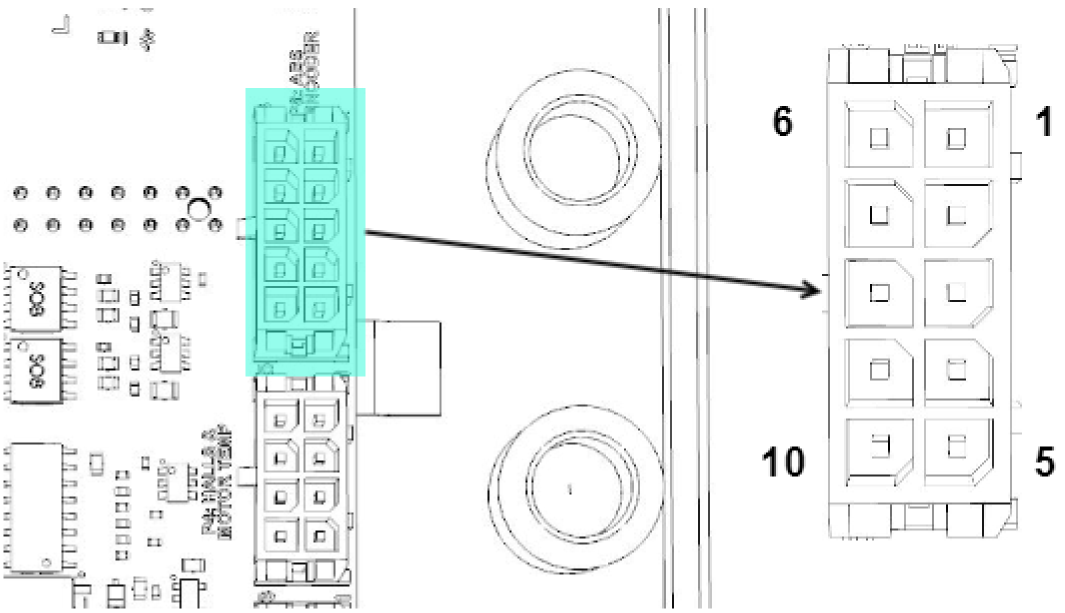
P7 Mating

Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 6 Circuits.
Image	
Part number	Molex 43025-0600
Distributor code	Digi-Key WM1785-ND / Mouser 538-43025-0600 / Farnell 672907
Notes	

- See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.

5.11 P8: Absolute Encoder

P8 connector



6 pin 2 row Micro-Fit™ 3.0, 3 mm pitch header. Molex.

Pin	Signal	Function for absolute encoder

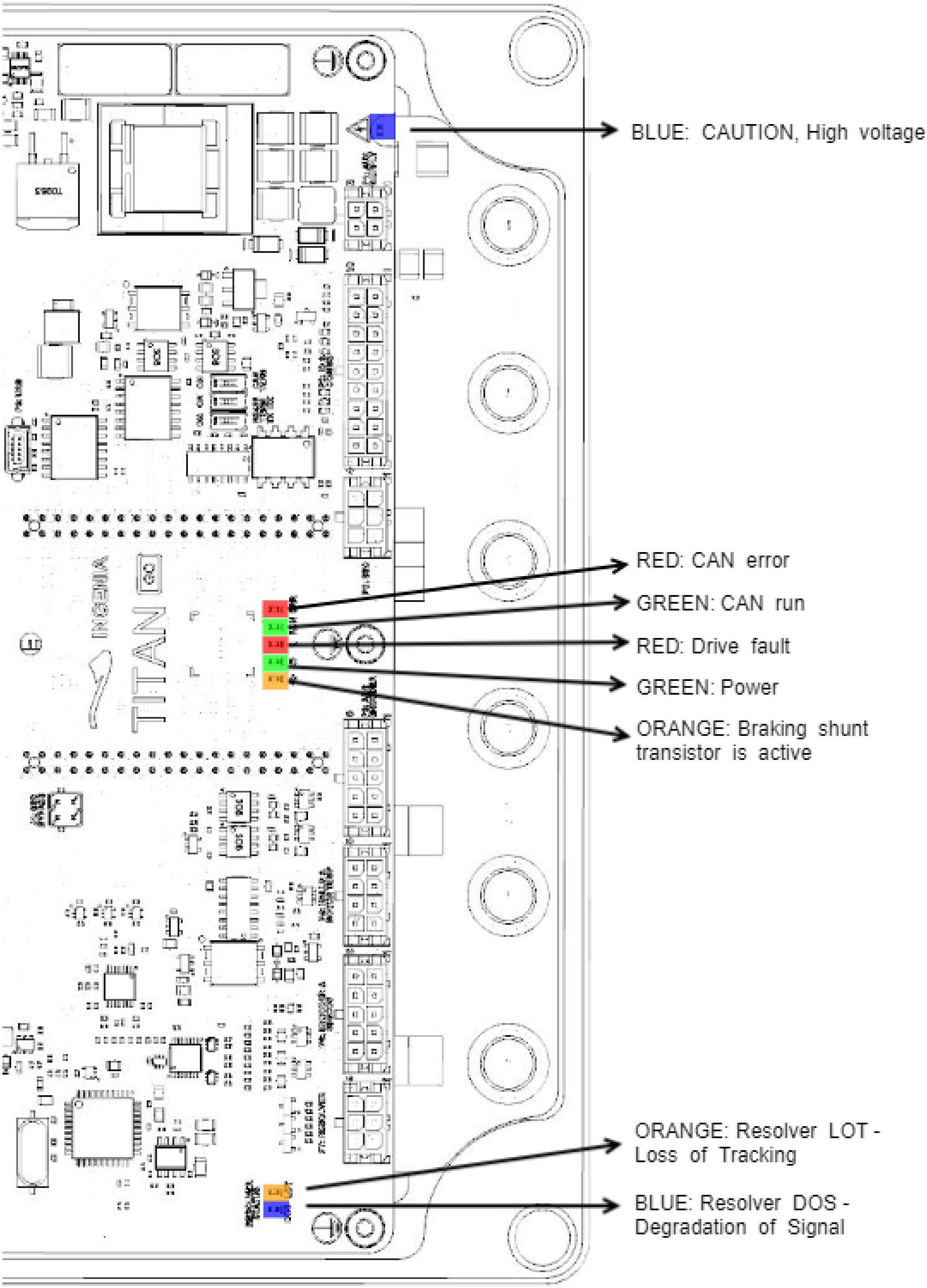
1	GND_D	Logic ground.
2	CLK+	Clock positive signal output
3	GND_D	Logic ground.
4	DIN+	Data positive signal input
5	NC	Not connected
6	+5V_OUT	5 V 200 mA regulated and short-circuit protected power supply for the encoder
7	CLK-	Clock negative signal output
8	GND_D	Logic ground.
9	DIN-	Data negative signal input
10	NC	Not connected
Notes		
This connector was added on version 1.2.0. Wiring is 100% compatible with connectors of version 1.1.0.		

P8 Mating	
Description	3.00mm Pitch, Micro-Fit™ 3.0 Receptacle Housing, 10 Circuits.
Image	
Part number	Molex 43025-1000
Distributor code	Digi-Key WM1787-ND / Mouser 538-43025-1000 / Farnell 672920
Notes	
• See Micro-Fit 3.0 connectors mating for further information about crimping terminals and cables.	

6 Signalling LEDs

Titan Go Servo Drive provides information through 6 signaling LEDs:

- Supply and operation: 2 LEDs below the Titan Go logo.
- Shunt resistor activation: 1 LED below the Titan Go logo.
- CANopen communication: 2 LEDs below the Titan Go logo.
- High voltage: 1 LED near the AUX Supply connector.
- Resolver Status: 2 LEDs. Near the Resolver connector.



6.1 Power and operation signalling LEDs

Three LEDs placed below the Titan Go GO logo indicate the supply and operation status.

LED	**Colour**	**Meaning**
POWER	**Green**	LED is on when internal power supply is working.
SHUNT	**Orange**	LED is turned on when the supply voltage is greater than the maximum voltage configured by the user. In this case the shunt braking transistor is connected. This signal will only work if the braking resistor output is configured as active.
FAULT	**Red**	LED is on when an error event has occurred and the drive is trapped in the **Fault state**. Find more about the Fault state in the E-Core documentation page.

6.2 CAN signalling LEDs

Two LEDs below the Titan Go logo 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 on bus-off condition.

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

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

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

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

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

6.3 Resolver status LEDs

6.3.1 Resolver LEDs

There are 2 LEDs close to the Resolver feedback connector. If the resolver is functioning correctly both LEDs should be off. They turn on when there is a problem with the Resolver or the Resolver is disconnected.

LED	**Colour**	**Meaning**
LOT	**Orange**	Loss of Tracking. Indicates that it is not possible to follow the resolver angle.

LED	Colour	Meaning
DOS	**Blue**	Degradation Of Signal. Indicates that the resolver signal is not well received. Typically when the resolver transformation ratio is not correct or noise is coupled to the lines.

When no resolver is connected, orange and blue LEDs are on.

6.3.2 Adjusting the resolver

Titan default setting is for a resolver with a transform ratio of 1:0.5. The transform ratio can be adjusted at Ingenia facilities. **Please notify the desired resolver specifications when ordering a Titan.**

The SIN and COS inputs expect a differential voltage (between positive and negative terminals) of 1.4 V_{RMS} or 3.9 $V_{pk-pk.}$ However, in some cases, it is possible to adjust the gain by adding a resistor in series with the SIN and COS inputs. This will make a voltage divider with the input differential resistance of 26 kΩ. When the gain is correct, the LOT and DOS LEDs are off.

Resolvers with independent rotor and stator require fine positioning. Ensure perfect collinearity between them and follow the resolver manufacturer instructions.
Both resolver LEDs (LOT and DOS) OFF indicate that the resolver is well positioned and wired.

1. Use Ingenia Motion Lab software to set up *resolver* as the position and/or commutation sensor for the driver. You can use CANopen or the USB port for this purpose.
2. With the **motor disabled** check the position read by the resolver. Rotate the motor and ensure that it's position is well read. Use Ingenia Motion Lab scope with position actual value register being monitored.
3. If the orange or blue LEDs are on this means incorrect resolver gain or alignment. Check the correct relative position between stator and rotor of the resolver. Use an oscilloscope to detect the amplitude of sine and cosine (differential) and ensure a **sine wave with desired amplitude is observed (peak 3.9Vp-p of sine and cosine at their maximum)**. Too much amplitude or too low causes a degradation of read signal Trick: The gain can be changed by sliding the resolver rotor inwards or outwards relative to the stator. (Z axis). This changes the reluctance and affects the transform ratio.
4. Enable the motor in **open loop vector mode, no current loop, no position or velocity loop**. Set frequency to 1 Hz or lower and start increasing the voltage gently. Use the motion window in motion lab. Observe that the motor starts moving. Read motor actual current with the scope.
5. Check that the resolver position is well-read. If reading errors appear only when the motor is on, this could mean some noise being coupled to the resolver and degrading the signal. Wire the resolver as far as possible from the power cables (to prevent noise coupling). Ensure a good thick and short cable connects the motor housing and the driver PE (Earth) contact. Connecting the motor housing to PE creates a short impedance path for coupled noise and therefore is not coupled to the resolver.
6. If the installation allows this to connect the motor housing to the main supply negative (GND). Only do so if an experienced electrician with perfect understanding of the installation and system knows that this is correct.
7. When no error appears with motor turning and active (orange and blue leds always off). You can proceed and configure the commutation sensor. After that configure the control loops, starting with the current loop.

7 Wiring and Connections

Proper wiring, and **especially grounding and shielding**, are essential for ensuring safe, immune and optimal servo performance of Titan Go Servo Drive. Please be sure to follow this detailed recommendations on connection and check the technical details of each interface.

- Protective earth
- Power supply
- DC bus bulk capacitance
- Motor and shunt braking resistor
- Feedback connections
- I/O connections
- Command sources
- Communications
- Safe Torque Off (STO)

7.1 Protective earth

Connection of Titan Go 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. Please check this document Electromagnetic Interference Issues With Servo Drive Systems.

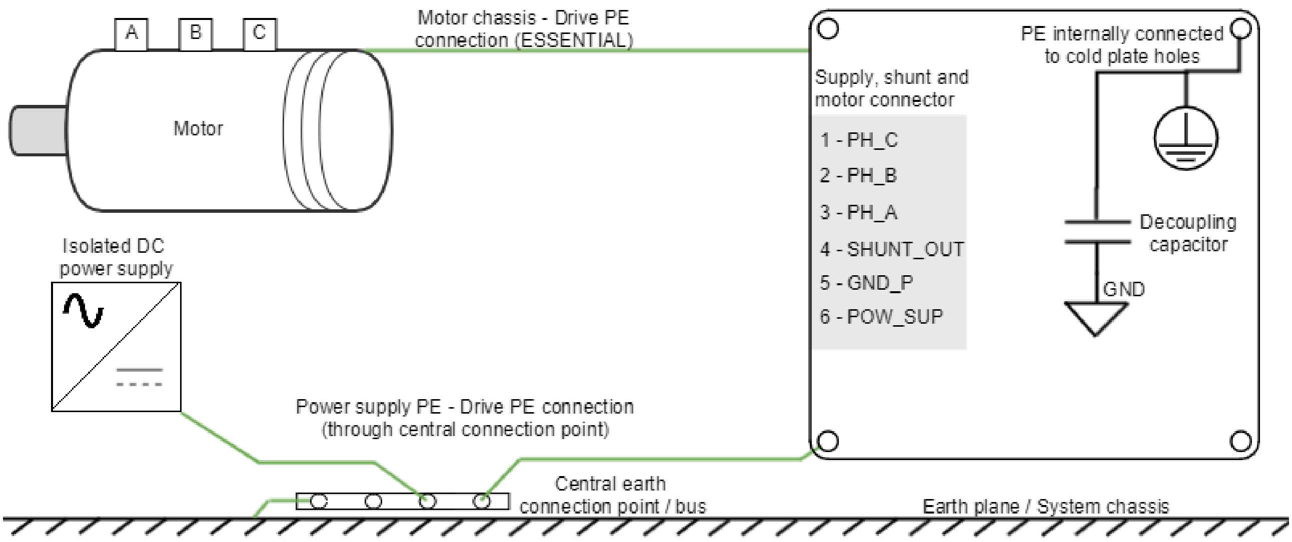
7.1.1 Reducing EMI susceptibility

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 safety capacitors. 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 EMI reduction.

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

- Cold plate is connected to PE.

A diagram of the recommended Earth wiring is shown below.



7.1.2 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.

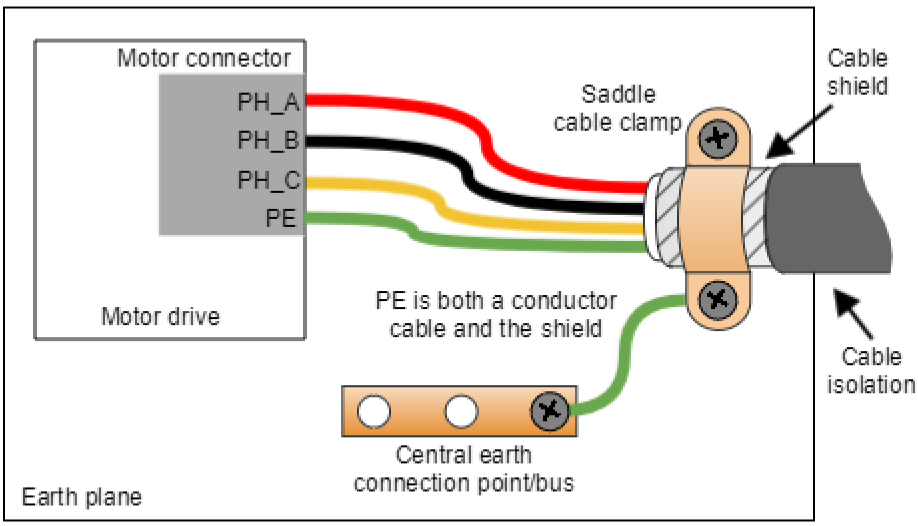
Some considerations for a proper earth connection are detailed next:

- Switching noise can be coupled to the earth through the housing of the motor. This high-frequency noise creates a 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, the **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 Titan Go 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 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 good support and connection** between the cable shield and the clamp. Following examples are only suggested for a conceptual purpose:

Description	Image	Part number
Cable Clamp Aluminum 31.75 mm		Essentra components AL20
Cable Clamp with Bolt Type Stainless Steel 76 mm		Panduit Corp PCD7B

7.2 Power supply

The Titan Go Servo Drive is powered from the Supply, shunt and motor connector. An internal isolated DC/DC converter provides the internal logic supply (+24 V_{DC}) to the circuits as well as regulated 5 V output voltage to supply feedback sensors and I/O. This power supply turns on at 60 V DC bus voltage.

> **Disconnection recommendations**
>
> **Please follow the following recommendations:**
>
> - The board could be hot during 5 min after disconnection.
> - Preferably do not disconnect the supply while having a motor in motion. The back EMF may create dangerous voltages.
> - 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 Titan Go power supply are:

- The **voltage** should be the targeted for the motor. This means up to **400 V** depending on the Titan Go variants. 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 **200 A** depending on the Titan Go variants. 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.

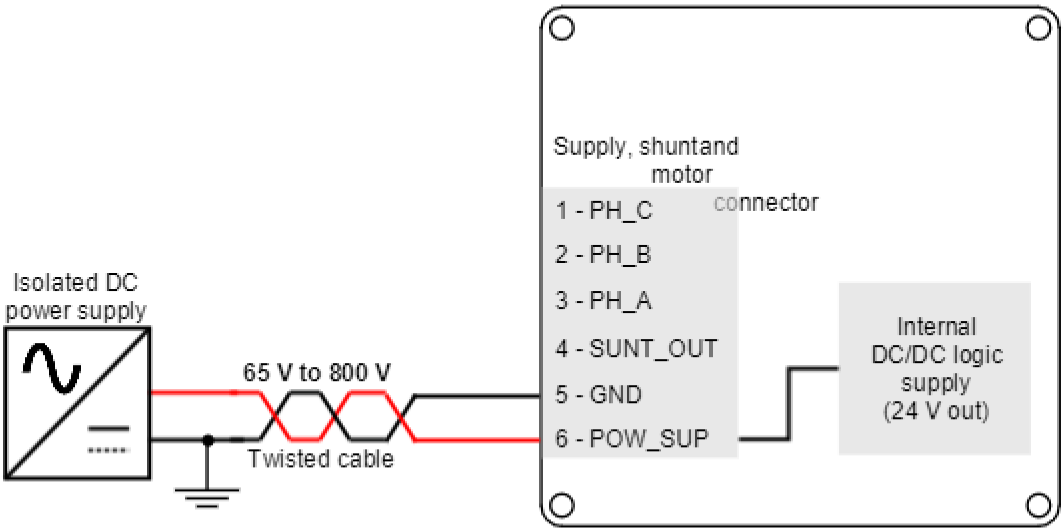
Further information on how to dimension a power supply for the Ingenia drives can be found here**.**

7.2.2 Power supply connection

Titan Go power and logic supply are provided through the same terminal. However, the Aux supply connector can be used to supply only the logic with a 24 V power supply (see below).

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

The following picture show the Titan Go supply wiring diagram using a single power supply. The logic supply is internally generated. **Note that the minimum power supply voltage is 65 V if single supply is used.**



Isolated power supplies

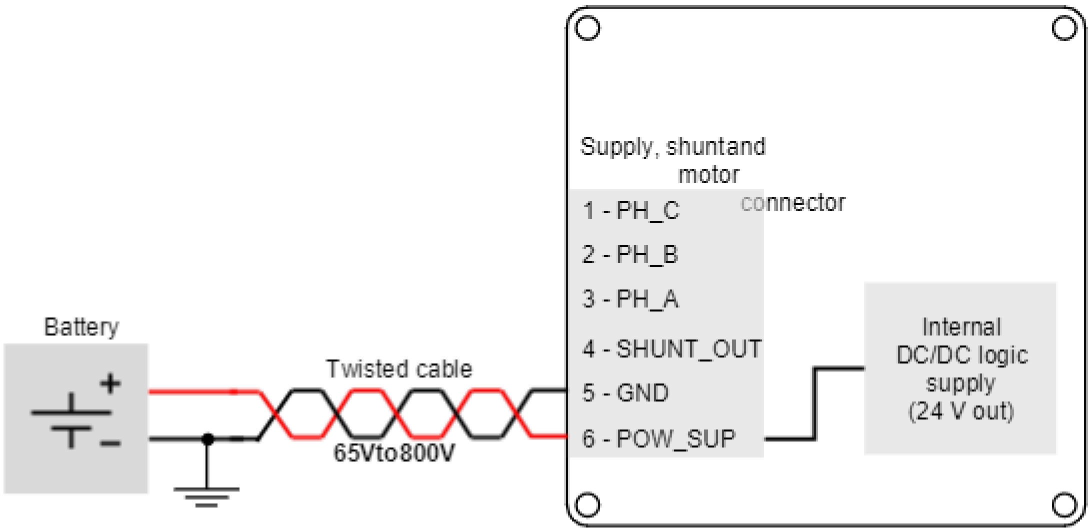
For safety reasons, it is important to use **power supplies with full galvanic isolation**.

Maximum power supply voltage

Please, note that the maximum nominal power supply voltage is different for each version of the Titan Go:
* Up to 200 V for TTN-xx/200-C-C
* Up to 400 V for TTN-xx/400-C-C
* Up to 800 V for TTN-xx/800-C-C
Do not supply with higher voltage, as the Titan Go could be damaged.

7.2.3 Battery supply connection

Next figure shows a simplified wiring diagram for the Titan Go Servo Drive supplied from a battery. The logic supply is internally generated. **Note that the minimum power supply voltage is 60 V if single supply is used.**



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 Titan Go current ratings.

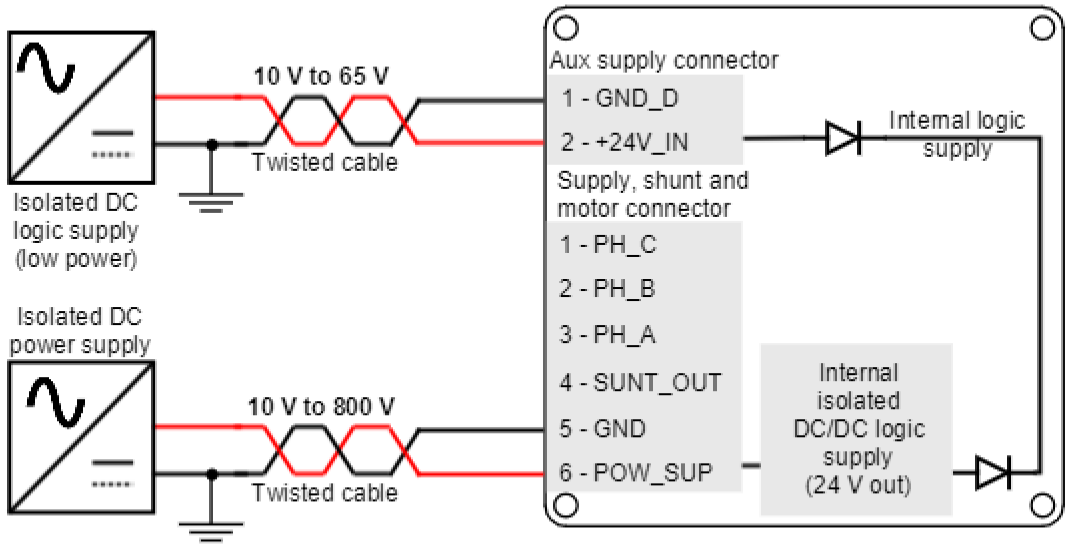
Maximum power supply voltage

Please, note that the maximum power supply voltage is different for each version of the Titan Go:
* Up to 200 V for TTN-xx/200-C-C
* Up to 400 V for TTN-xx/400-C-C
* Up to 800 V for TTN-xx/800-C-C
Do not supply a higher voltage, as the Titan Go could be damaged.

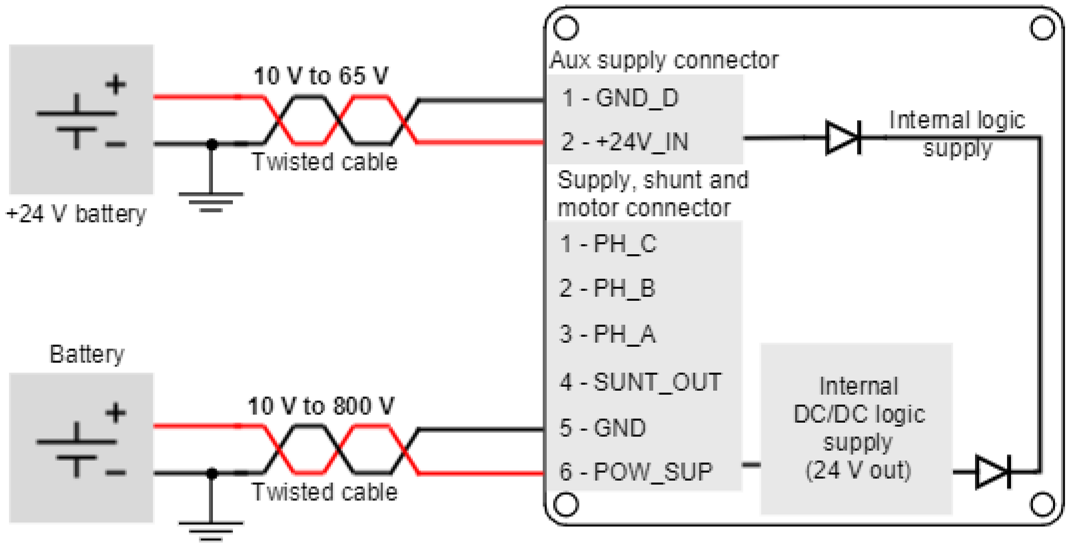
7.2.4 Dual supply connection

In some cases it could be needed to supply the logic sepparated from the power. In that cases, the AUX_SUP connector can be used. Next figure shows a simplified wiring diagram for the Titan Go Servo Drive with dual supply. The power consumption of the logic when the power stage is enabled is near 15 W, so the logic power supply must be choses with at least this rated power.

The following picture show the Titan Go supply wiring diagram using a dual power supply. An internal diode connects to the internal +24 V logic supply. **Note that the minimum power supply voltage is 10 V if dual supply is used.**



Next figure shows a simplified wiring diagram for the Titan Go Servo Drive supplied from two batteries. **Note that the minimum power supply voltage is 10 V if dual supply is used.**

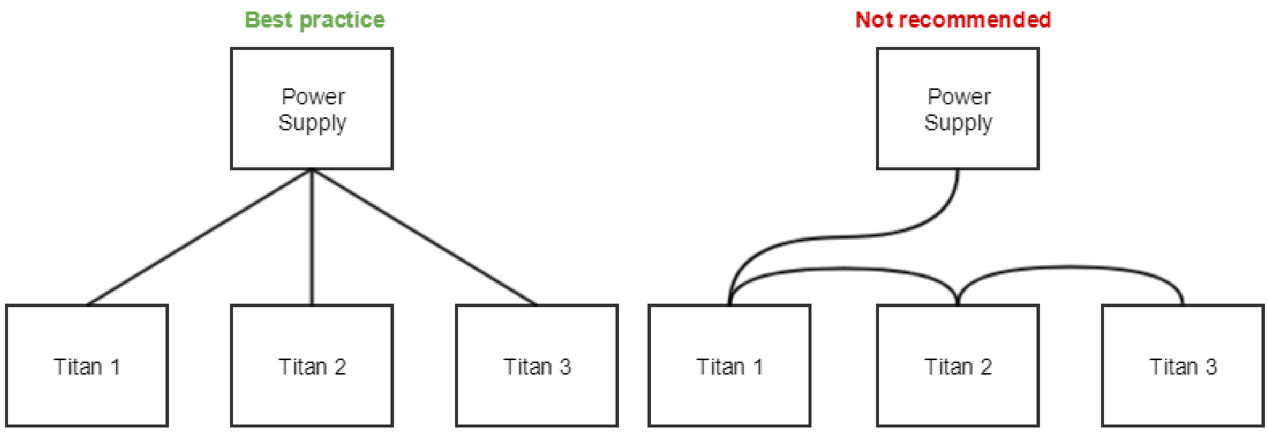


Maximum power supply voltage

Please, note that the maximum power supply voltage is different for each version of the Titan Go:
* Up to 200 V for TTN-xx/200-C-C
* Up to 400 V for TTN-xx/400-C-C
Do not supply a higher voltage, as the Titan Go could be damaged.

7.2.5 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.



7.2.6 Power supply wiring recommendations

7.2.6.1 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. Following table indicates recommended wire sections:

Connection	Minimum wire size	Maximum wire size
Stranded wire (preferred)	8.4 mm^2 (8 AWG)	33.6 mm^2 (2 AWG)
Solid wire	8.4 mm^2 (8 AWG)	33.6 mm^2 (2 AWG)

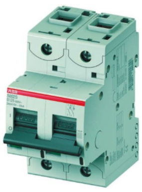
In case of using buss bars please take care not to exceed the terminal torque.

7.2.6.2 Wire length

- The distance between the Titan Go 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.

7.2.6.3 Supply protection

It is strongly recommended to use an over-current protection between the drive and the DC power supply. Both a fuse or a DC circuit breaker can be used. Class B or Z would be prefered, typically rated for semiconductor, control or photovoltaic applitations. Take the following as suggested parts:

Manufacturer	Part Number	Image	Description
ABB	2CCP842001R1849		125 A, 600 V_{DC} circuit breaker.
ABB	2CCS862001R0845		125 A, 250 V_{DC}, class B circuit breaker.

Manufacturer	Part Number	Image	Description
Littelfuse	L70S200.V		200 A, 650 V_{DC} fast-blow fuse. Can be directly screwed to Titan M8 terminals.
Eaton Bussmann	FWH-200B		200 A, 500 V_{DC} fuse. Can be directly screwed to Titan M8 terminals.

7.2.7 Logic power supply

Following are shown different power supply examples for logic.

Manufacturer	Part Number	Rated Voltage (V)	Rated Current (A)	Image	Description
Tamura	TCDC-7001	24 V	1 A		Isolated wide DC input (190 V to 1000 V) range switching closed frame power supply recommended for dual supply with batteries. Use only to power the logic.
TDK-Lambda	DSP30-24	24 V	1.3 A		AC input switching closed frame power supply recommended for dual supply. Use only to power the logic.

7.3 DC bus bulk capacitance

Certain applications will require additional DC bus capacitance. Typically extra capacitors are needed in applications with long supply cables (with high parasitic inductance or resistance) or where the power supply does not tolerate a high current ripple. Adding the extra capacitors reduces the ripple current on supply lines and therefore reduces losses as well as electromagnetic interference (EMI). For best results, the capacitors should be connected to the DC link terminals on the back of the Titan. Since this drive includes automatic precharge circuits, there is no need for additional and bulky relays or precharge resistors.

For the Titan voltage and power ratings, Ingenia recommends **metallized polypropylene film capacitors (MKP)**, as they provide the best trade-off of capacitance, ripple current and long term reliability.

Electrolytic capacitors provide higher energy density and lower cost, however only good quality, **low ESR** and high current **ripple current** are acceptable. Current ripple of the capacitor bank should be at least 0.4 * motor rated rms current at its operating temperature. Electrolytic capacitors must have low series resistance and be prepared for high current, otherwise they may overheat and be damaged. High power density applications could be also based on ceramic capacitors, however cost would increase dramatically. Custom versions of Titan can be provided with extra DC bus ceramic capacitance.

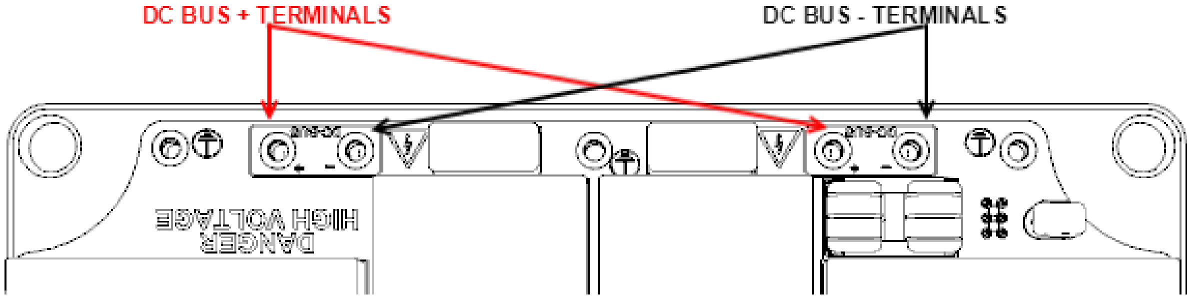
Next there are some suggested capacitors that should be attached to the DC link terminals (not to the input supply):

Manufacturer	**Part number**	**Capacitance / Technology**	**Rated Voltage**	**Photo**	**Dimensions**	**Comments**
Kemet	C4DEFPQ6380A8TK	480 µF MKP	400 VDC		Diameter 84.0 mm x 66.0 mm (height)	Good trade off of capacitance / price. Height exceeds the Titan.
Panasonic	EZT-VKCTYP1HA	581 µF MKP	450 VDC		164.0 mm x 115.0 mm x 43.0 mm (height)	Height is < Titan. This makes a low profile solution.
EPCOS	B25655P4707K031	700 µF MKP	450 VDC		237.0 mm x 72.0 mm x50.0 mm (height)	-
EPCOS	B25655P4108K031	1000 µF MKP	450 VDC			Highest capacitance option on metal film. High cost.

Manufacturer	**Part number**	**Capacitance / Technology**	**Rated Voltage**	**Photo**	**Dimensions**	**Comments**
Cornell Dubilier Electronics (CDE)	947D421K901BDMSN	420 µF MKP	900 VDC		Diameter 90.0 mm x 88.0 mm (height)	Good capacitance / price. Height exceeds the Titan. Recommended for 800 V version.
Cornell Dubilier Electronics (CDE)	947D601K901DCRSN	600 µF MKP	900 VDC		Diameter 116.0 mm x 76.0 mm (height)	Good capacitance / price. Height exceeds the Titan. Recommended for 800 V version.
United Chemi-Con	E37F351CPN223MFM9M	22000 µF Aluminum electrolytic	350 VDC		Diameter 89 mm x height 220 mm	Very high capacitance. 46.7 A ripple current. 4 mΩ ESR.
Nichicon	LNC2G123MSEJ	12000 µF Aluminum electrolytic	400 VDC		Diameter 90 mm x height 148 mm	High capacitance. 37.1 A ripple current. Comes with assembly bracket. Low cost.

Follow these recommendations:

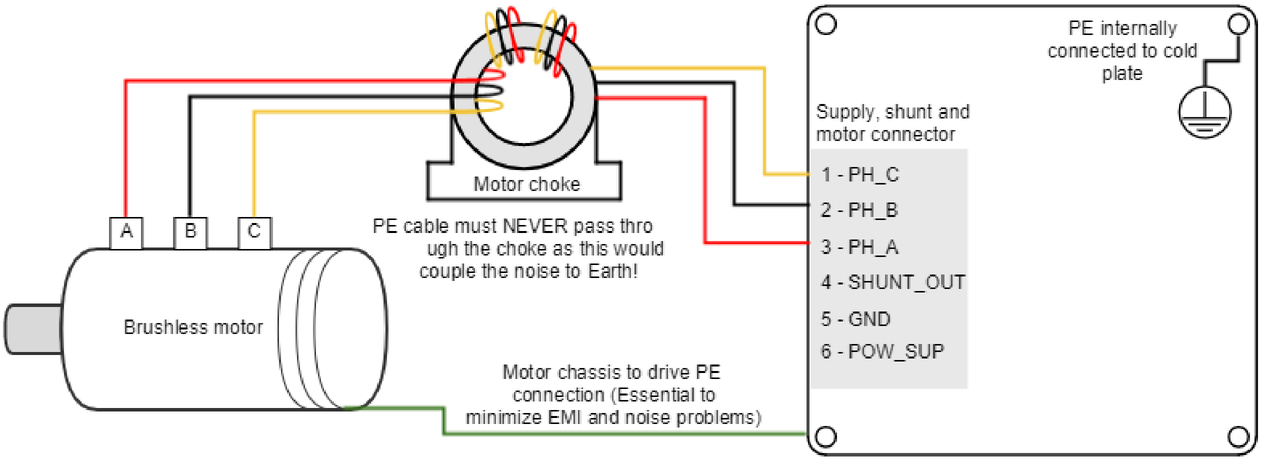
- Use thick, as short as possible cables between the DC bus capacitor and the Titan.
- Use the internal DC bus terminals to add the capacitance needed (see below).
- Use M3 ring terminals like Phoenix Contact to connect to the internal DC bus terminals.


DC BUS + TERMINALS
DC BUS - TERMINALS

7.4 Motor and shunt braking resistor

7.4.1 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

STO

Safe torque off inputs must be enabled in order to deliver power to the motor. If the Safe Torque Off inputs (Connector P3) are not connected an error will appear and the driver will not power the motor.

Common-mode choke

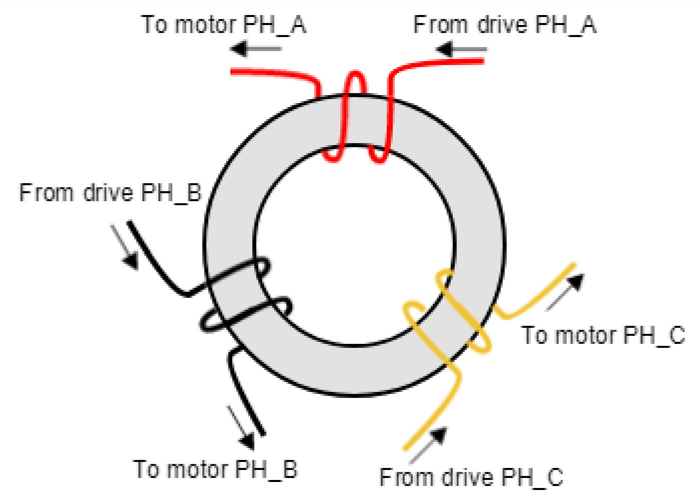
In order to minimize EMI that can affect sensitive signals, the use of a **motor choke** is highly recommended. The objective of the motor choke is to **block the common mode current** to the motor and cables. While using a separate choke for each phase could also work, the EMI reduction would be much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

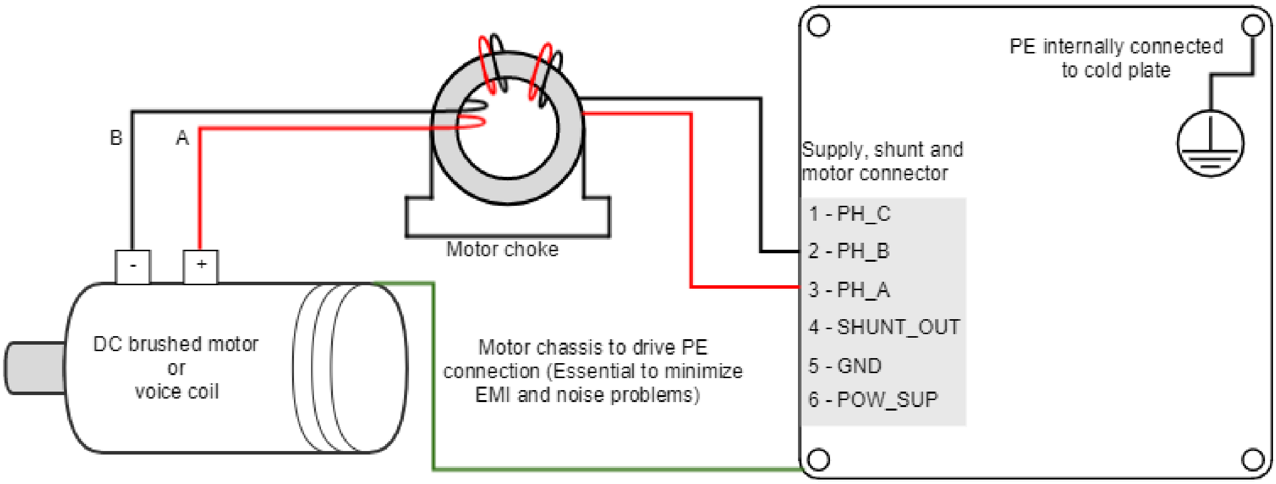
- An excessive number of turns causes a high capacitive coupling. Only 2 or 3 turns per motor phase are recommended.

- 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.
- Remind that PE cable must NEVER pass through the choke as this would couple the noise to Earth.



7.4.2 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.



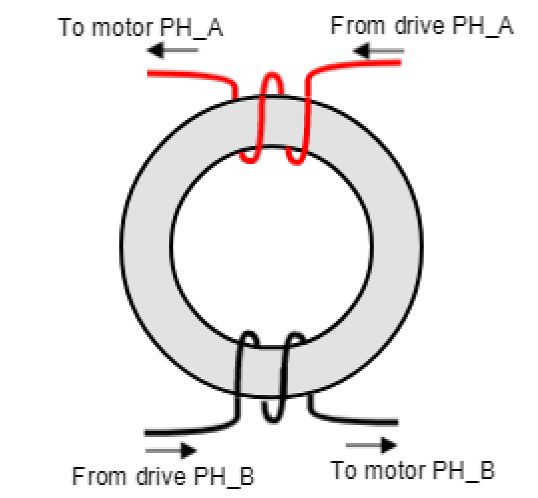
Common-mode choke

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.



7.4.3 Motor wiring recommendations

7.4.3.1 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. Following table indicates recommended section for the Titan Go Servo Drive:

Connection	**Minimum wire size**	**Maximum wire size**
Stranded wire (preferred)	8.4 mm^2 (8 AWG)	33.6 mm^2 (2 AWG)
Solid wire	8.4 mm^2 (8 AWG)	33.6 mm^2 (2 AWG)

7.4.3.2 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 Titan Go Servo Drive specifications and has a great performance at low frequencies.

Type	Manufacturer	Reference
Ferrite toroid	Magnetics	ZJ49740TC
Ferrite toroid	Magnetics	ZJ49740TC

7.4.3.3 Wire length

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

7.4.4 Shunt braking resistor

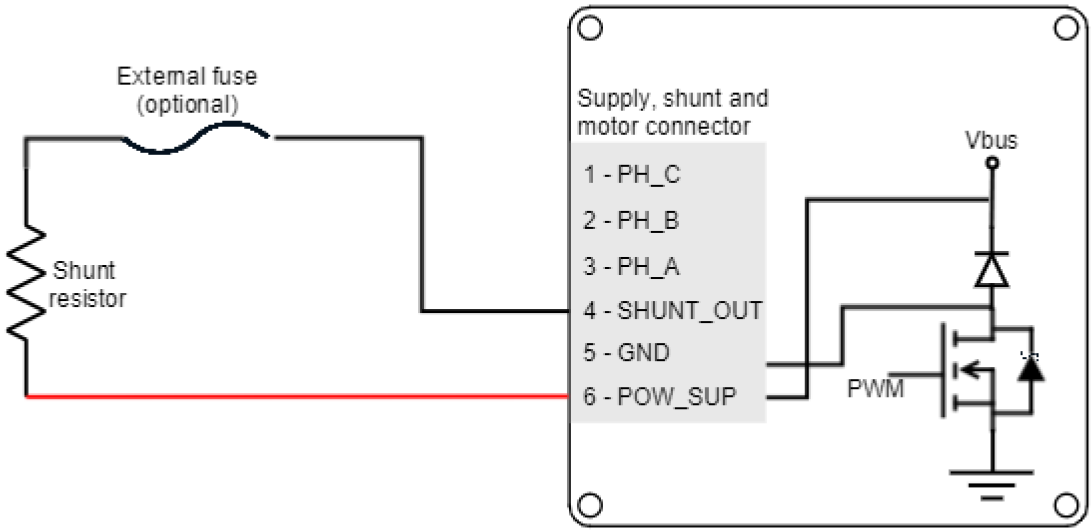
While decelerating a motor (abrupt motion brakes or reversals), the mechanical energy is converted into electrical energy by the motor. This energy is regenerated into the power supply and could lead to an increase of the supply voltage. To absorb this energy the Titan Go **incorporates a shunt transistor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

7.5 Feedback connections

The Titan Go Servo Drive has multiple connectors (Halls and motor temperature connector, Digital/Absolute encoder connector and Resolver connector) dedicated to the following feedback options:

- Digital Halls
- Quad. Incremental encoder
- Absolute encoder
- Resolver

Additional feedback connections can be found on Communications and IOs connector:

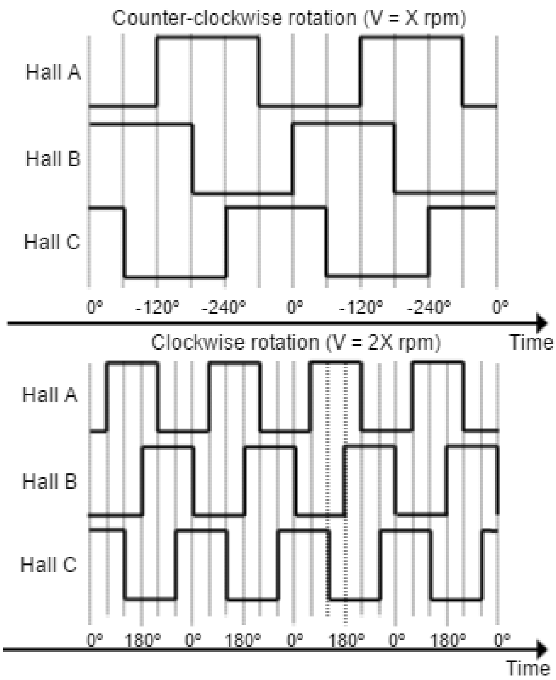
- PWM encoder
- Analog input for potentiometer
- Analog input for DC tachometer

Titan also provides a 5 V, 50 mA output for Halls supply and a 5 V, 200 mA output for Encoders supply. These outputs are overload and short circuit protected.

7.5.1 Digital Halls interface

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

Digital halls signals example

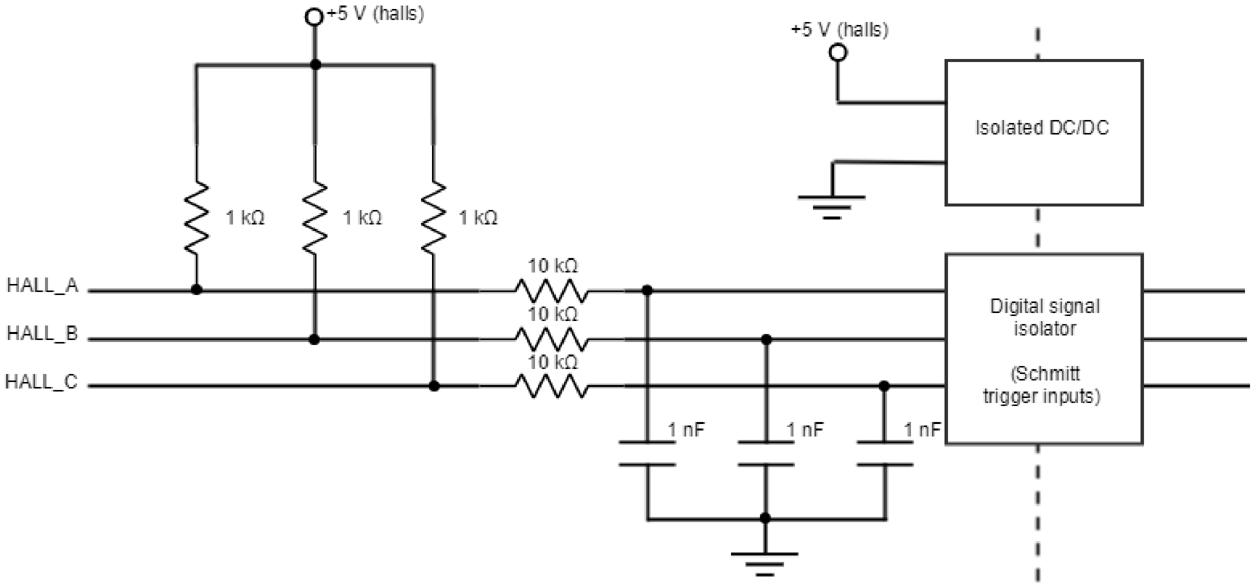


Digital halls can be used for commutation, position and velocity control. Resolution using these sensors is much lower than using encoders. **Titan Go can use single ended Hall sensors to drive the motor with trapezoidal commutation, but not with sinusoidal commutation.**

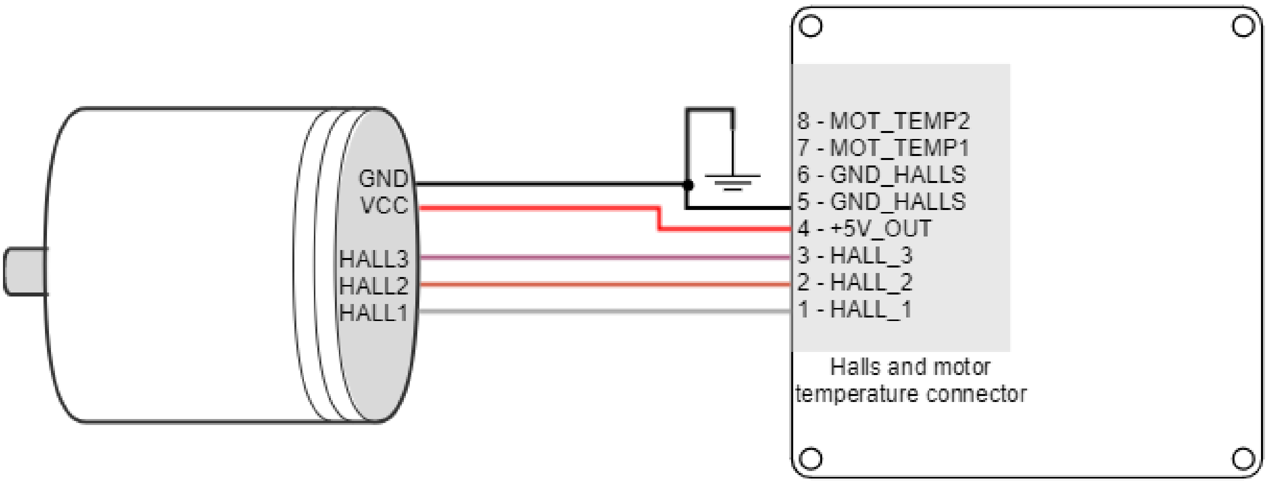
This interface accepts 0-5 V level input signals. Inputs are pulled up to 5 V, so industry standard open collector and logic output hall effect sensors can be connected. Next table summarizes digital halls inputs main features:

Specification	**Value**
Type of inputs	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)
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)	16 kHz
Sampling frequency	10 ksps
Type of sensors	Open collector Logic output Push-pull output
Pull-up resistor value	1 kΩ

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



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



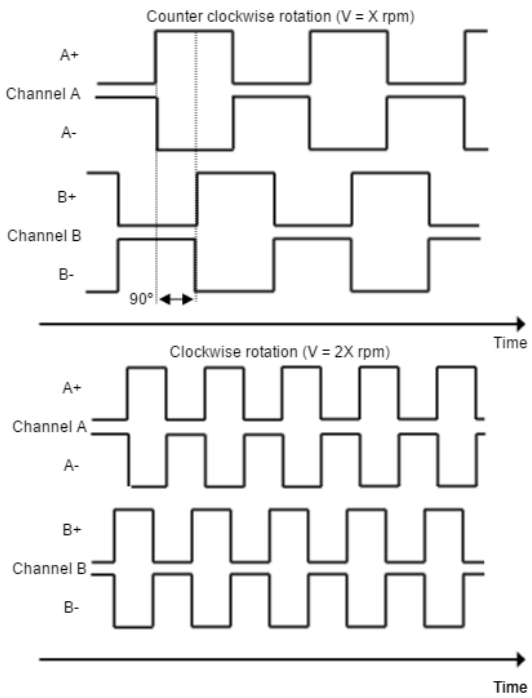
> **Velocity control with Halls**
>
> Due to inherent low resolution of motor mounted Hall sensors, they are not recommended for velocity feedback in low speed applications.

7.5.2 Digital Incremental Encoder

Titan Go can use 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 Titan Go 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 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.

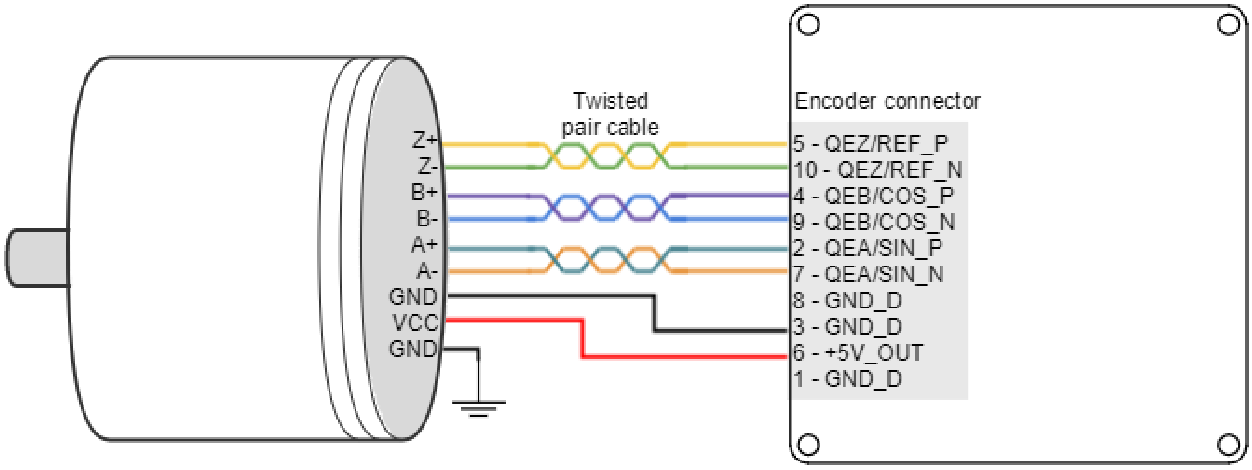
The Titan Go Servo Drive has one differential digital encoder interface, with optional index signal input. Index (Z) is a single pulse per revolution signal that indicates an absolute position. Next table lists digital encoder inputs main features.

Specification	Value
Type of inputs	Non-isolated. Differential. ESD protected
Number of inputs	3 (A, B and Index)
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Nominal voltage range	0 ~ 5 V
Maximum voltage range	-15 ~ 15 V
Maximum recommended working frequency	10 MHz (differential)

Specification	Value
1st order filter cutting frequency (-3 dB)	6 MHz
Maximum readable pulse frequency	30 MHz
Termination resistor	470 Ω (between ENC_x+ and ENC_x-)
Bias resistors	ENC_x- (negative input) 1 kΩ to 3.3 V (equivalent)

The encoder interface accepts an RS-422 differential quadrature line driver signal in the range of 0 V to 5 V, up to 10 MHz.

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



7.5.3 Absolute encoder interface

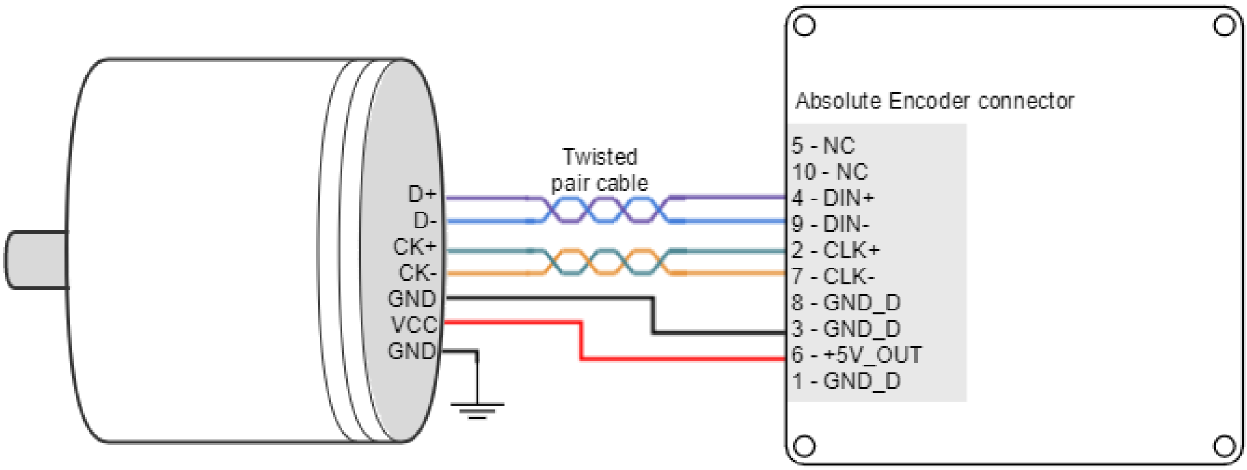
The Titan Go has an Absolute encoder connector that can be used as position and velocity feedback element. This sensor generates digital data that represent the encoder actual position. From the position information, speed and direction of motion is calculated. The position is not lost even if the encoder is powered down, this means it is not necessary to move to a reference position as with incremental type encoders.

Next table shows the absolute encoder inputs electrical specifications.

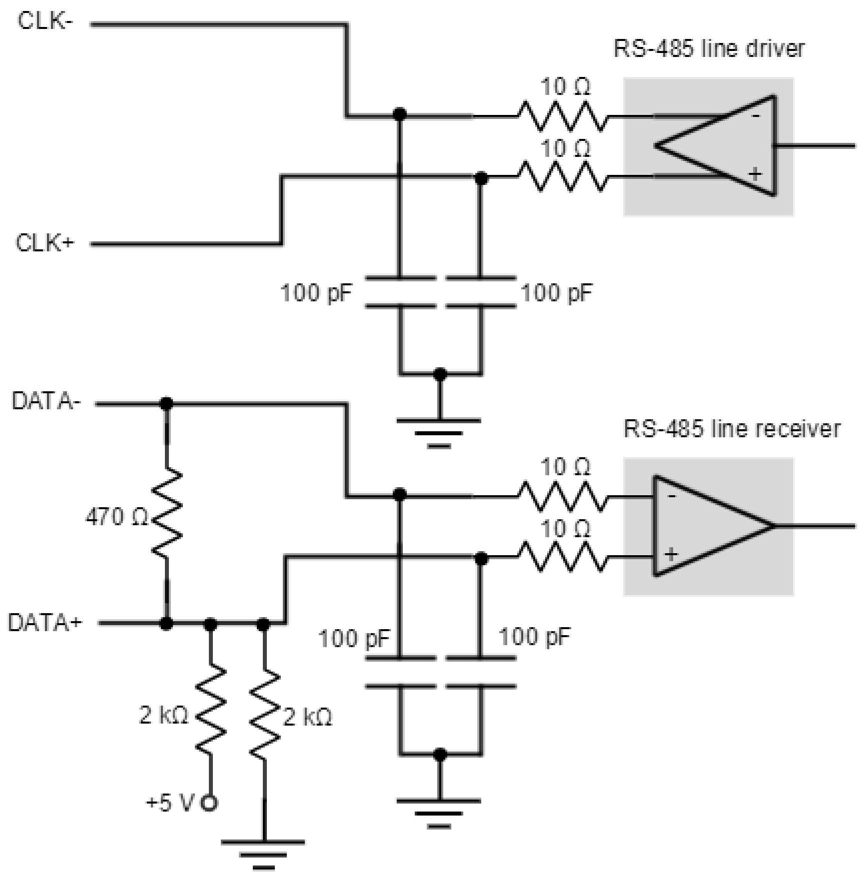
Specification	Value
Type of inputs	Non-isolated. Differential. ESD protected
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Number of inputs	2 (CLK and DATA_IN)

Specification	Value
Nominal voltage range	0 ~ 5 V
Maximum voltage range	-15 ~ 15 V
Maximum readable frequency	1 kHz
Termination	470 Ω

Next Figure shows how to connect an Absolute encoder to Titan Go Servo Drive. Refer to Feedback wiring recommendations for more information about connections and wires.

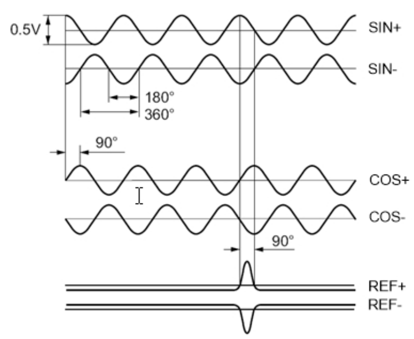


Circuit model for the absolute encoder receiver channels is shown in the next figure.



7.5.4 Analog encoder (Sin-Cos encoder) interface

The Titan Go can use analog encoder (also known as Sin-Cos encoder) as position and velocity feedback element. This sensor provide a pair of quadrature sine and cosine signals as the motor moves, which frequency depends on the motor speed. The signals may be generated by optical or magnetic means. For noise immunity the signals are typically transmitted differentially from the encoder to the sensor interface electronics.

Pin	Signal description	Signal example
SIN+	Sine wave with 2.5 V offset and 0.5 Vpp	
SIN-	Same as SIN+, but with 180º phase shift	
COS+	Cosine with 2.5 V offset and 0.5 Vpp	
COS-	Same as COS+, but with 180º phase shift	

Pin	Signal description	Signal example
REF+	One sine half wave per revolution as index pulse	
REF-	Same as REF+, but with 180º phase shift	

Sin-Cos calibration

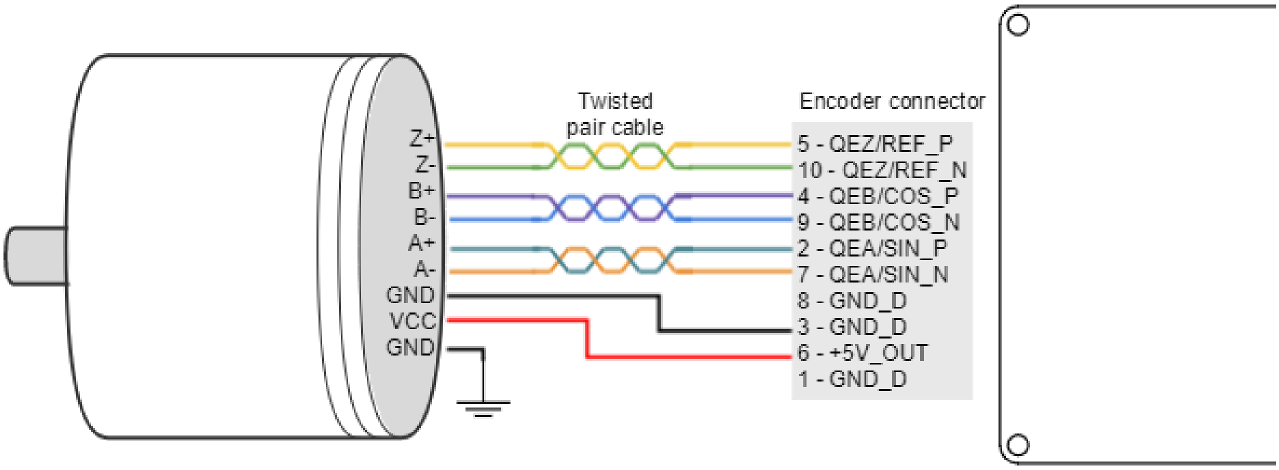
Analog encoder signals are not always perfect sine and cosines. For this reason, Titan includes sin-cos calibration and adjustment parameters. For further information see the E-Core registers for Sin-Cos encoder configuration.
An automatic calibration based on Lissajous curves is included in MotionLab, which allows an easy feedback adjustment.

Next table summarizes analog encoder inputs main features.

Specification	Value
Type of inputs	Differential analog input (switching to digital automatically at high speed) ESD protected
Number of inputs	3 (SIN, COS, REF)
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact) IEC 61000-4-4 (EFT) 40 A (5/50 ns)
Typical voltage range	2.25 ~ 2.75 V
Maximum voltage range	-0.5 ~ 5.5 V
Maximum recommended working frequency	1 kHz used as analog encoder 10 MHz used as digital encoder
1st order filter cutting frequency (-3 dB)	6.6 MHz
Sampling rate (analog)	10 ksps
Maximum readable pulse frequency (digital)	30 MHz
Input impedance	120 Ω resistive differential 100 pF capacitive 1 kΩ to GND

Specification	**Value**
Resolution	10 bits

Next figure shows how to connect a Sin-Cos encoder to Titan Go. Refer to Feedback wiring recommendations for more information about connections and wires.



Circuit model for each differential channel (A, B, REF) is shown in the next figure.

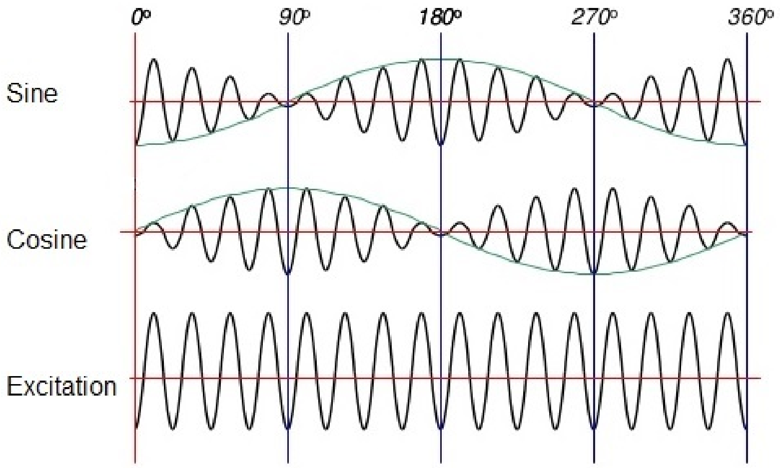
Please wait for the page to refresh...

Linking drawing automatically to page **Feedback connections**

7.5.5 Resolver interface

The Titan Go has a Resolver connector that can be used as position and velocity feedback element, as well as commutation sensor. A resolver is an electromagnetic transducer that can be used in a wide variety of applications. Because of its simple transformer design and lack of any on board electronics, the resolver is a much more rugged device than most any other feedbacks, specially in extreme conditions (high temperature, shock and vibration, radiation and contamination). The resolver needs an excitation signal generated by the drive, which is modulated in proportion of the sine and cosine of the angle of mechanical rotation. The sine and cosine signals are read by the drive and processed by the drive to know the rotor position. Next figure show an example of digital resolver signals.

Example of resolver signals

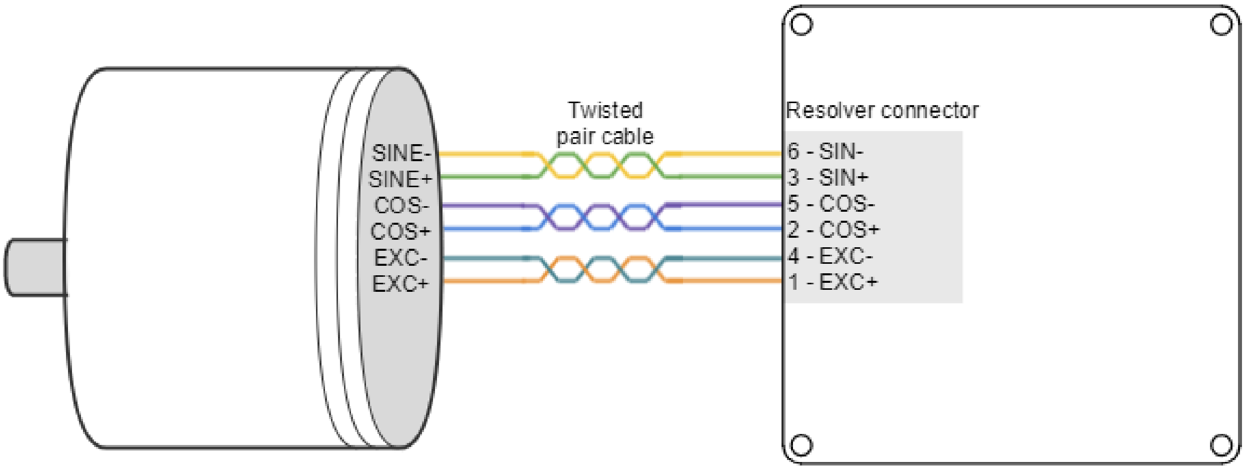


Next table shows the resolver electrical specifications.

Specification	Value
Type of inputs	Non-isolated. Differential. ESD protected
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Number of inputs	2 (SIN and COS)
Number of outputs	1 (EXC)
Excitation signal voltage	10.8 V_{pp} (7.6 V_{AC}) *
Excitation frequency	10 kHz *
Transform ratio	1:0.5 *

*These values can be adjusted to the customer needs on demand. Please, notify the desired resolver specifications when ordering a Titan Go.

The following picture shows how to connect the resolver to the Titan Go servo Drive:



Adjusting the resolver

7.5.5.1 Resolver Gain

Titan default setting is for a resolver with a transform ratio of 1:0.5. The transform ratio can be adjusted at Ingenia facilities. **Please notify the desired resolver specifications when ordering a Titan.**

The SIN and COS inputs expect a differential voltage (between positive and negative terminals) of 1.4 V_{RMS} or 3.9 $V_{pk-pk.}$ However, in some cases it is possible to adjust the gain by adding a resistor in series with the SIN and COS inputs. This will make a voltage divider with the input differential resistance of 26 kΩ. When the gain is correct, the LOT and DOS LEDs are off.

7.5.5.2 Configuring the resolver

> Resolvers with independent rotor and stator require fine positioning. Ensure perfect collinearity between them and follow the resolver manufacturer instructions.
> **Both resolver LEDs (LOT and DOS) OFF indicate that the resolver is well positioned and wired.**

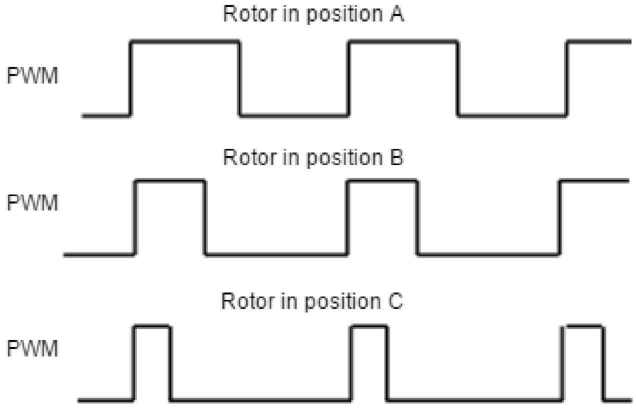
1. Configure that resolver is the position and or commutation sensor of the driver. Use Ingenia Motion Lab software for the configuration. Use CANopen or USB for the purpose.
2. With **motor disabled** check the motor position read by the resolver. Rotate the motor and ensure that position is well read. Use Ingenia Motion Lab scope with position actual value register being monitored.
3. If some of the orange or blue LEDs are on this means incorrect resolver gain or alignment. Check the correct relative position between stator and rotor of the resolver. Use an oscilloscope to detect the amplitude of sine and cosine (differential) and ensure a **sine wave with desired amplitude is observed (peak 3.9Vp-p of sine and cosine at their maximum)**. Too much amplitude or too low causes a degradation of read signal Trick: The gain can be changed by sliding the resolver rotor inwards or outwards relative to the stator. (Z axis). This changes the reluctance and affects the transform ratio.
4. Enable the motor in **open loop vector mode, no current loop, no position or velocity loop**. Set frequency to 1 Hz or lower and start increasing the voltage gently. Use the motion window in motion lab. Observe that the motor starts moving. Read motor actual current with the scope.
5. Check that the resolver position is well read. If reading errors appear only when the motor is on, this could mean some noise being coupled to the resolver and degrading the signal. Wire the resolver as far as possible from the power cables (to prevent noise coupling). Ensure a good thick and short cable connects the motor housing and the driver PE (Earth) contact. Connecting the motor housing to PE creates a short impedance path for coupled noise and therefore is not coupled to the resolver.

6. If the installation allows this connect the motor housing to the main supply negative (GND). Only do so if an experienced electrician with perfect understanding of the installation and system knows that this is correct.
7. When no error appear with motor turning and active (orange and blue leds always off). You can proceed and configure commutation sensor. After that configure the control loops, starting with the current loop.

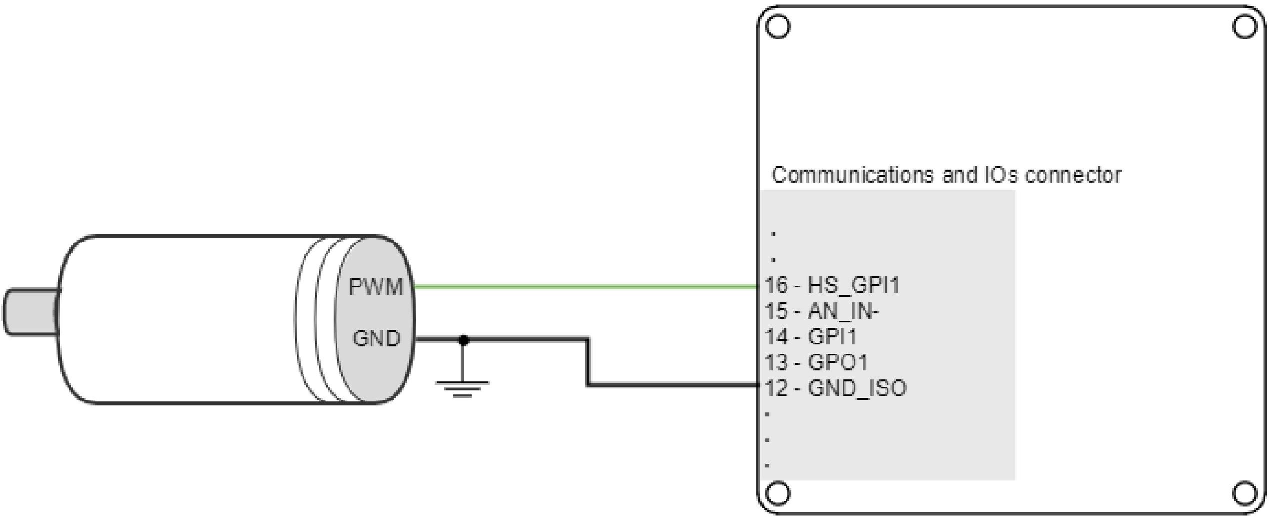
7.5.6 Digital input feedback - PWM encoder

Titan Go Servo Drive can also use a PWM encoder connected through the Communications and IOs 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**). Only single ended 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 figures illustrates how to connect differential and single ended PWM encoders to the Titan Go Servo Drive:



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

7.5.7 Analog input feedback

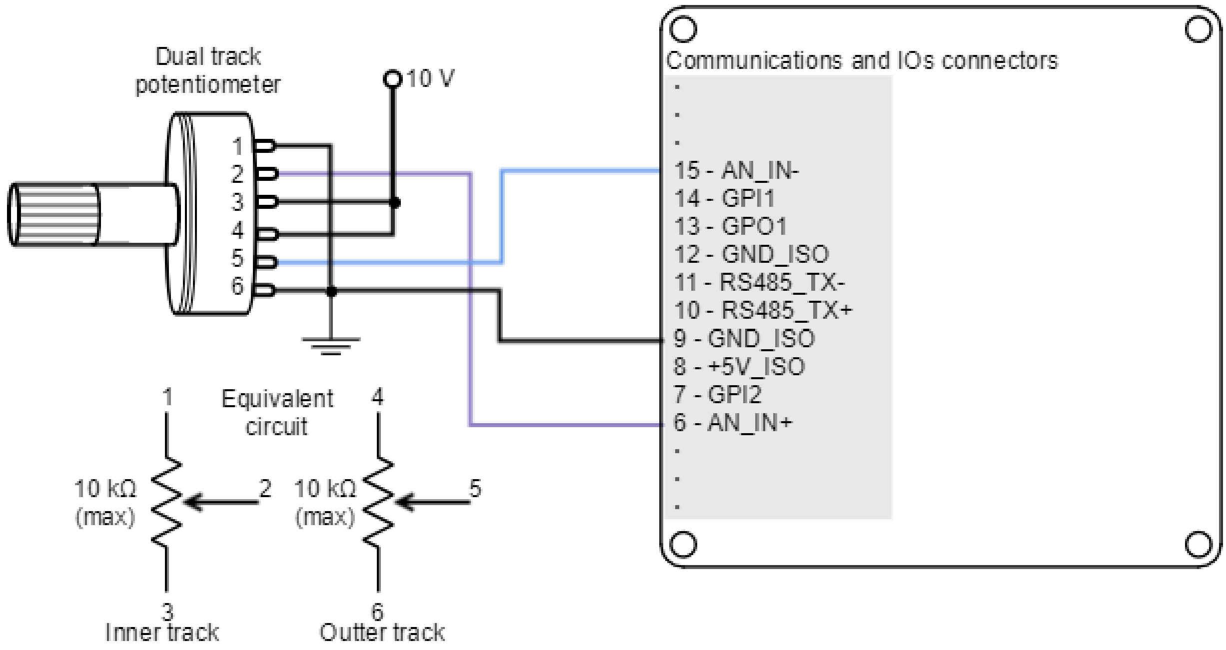
Titan Go Servo Drive can also use analog feedback systems connected through the Communications and IOs connector. From the voltage level of one analog input, the position or velocity of the rotor can be calculated. The Titan Go have 1 differential analog input that can be used for feedback input, with a range of ±10 V. The input used as feedback can be selected by software.

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

7.5.7.1 Potentiometer

Typically, a potentiometer is used as a postition feedback, providing a a voltage proportional to the rotor position.

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

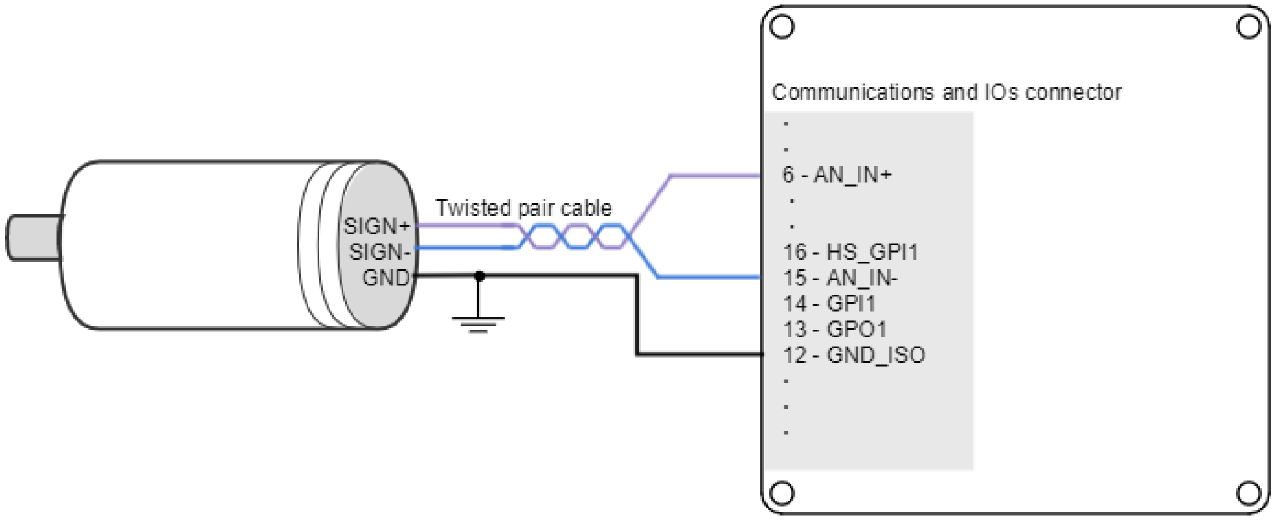


> **Recommended potentiometer resistance**
>
> Potentiometers with high values of resistance (> 10 kΩ) can result in non linear behavior due to its the drive parallel input resistors. High resistance values also reduce the signal to noise ratio, making it easier to have disturbances and reducing the 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 (safety margin to prevent self heating).
> - Does not exceed the +5V_OUT current capacity.
>
> Typically 1 kΩ to 10 kΩ will be preferred.

7.5.7.2 DC tachometer

The Titan Go Servo Drive can use a DC tachometer for velocity feedback through the Communications and IOs 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 Titan Go Servo Drive.



7.5.8 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 Titan Go and encoder GND signals** even if the encoder supply is not provided by the drive.
- **Connection between Titan Go 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.

7.5.8.1 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.

7.6 I/O connections

The Titan Go 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:

- 3 x 5 V general purpose isolated single ended digital inputs (GPI1, GPI2, GPI3).
- 2 x 5 V high-speed isolated single ended digital inputs (HS_GPI1, HS_GPI2).
- 1 x ±10 V isolated differential 12 bits analog input (AN_IN1).
- 1 x 3.3 V isolated digital output (GPO1).

Apart from the general purpose inputs, Titan Go has a dedicated analog input for measuring the motor temperature.

Wiring recommendations

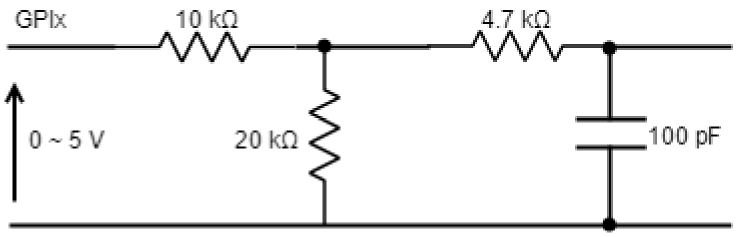
Wiring recommendations for I/O signals are the same than for feedback signals. Detailed information about good wiring practices can be found in Feedback wiring recommendations.

7.6.1 Low-speed and High-speed single ended digital inputs interface (GPI1, GPI2, GPI3, HS_GPI1, HS_GPI2)

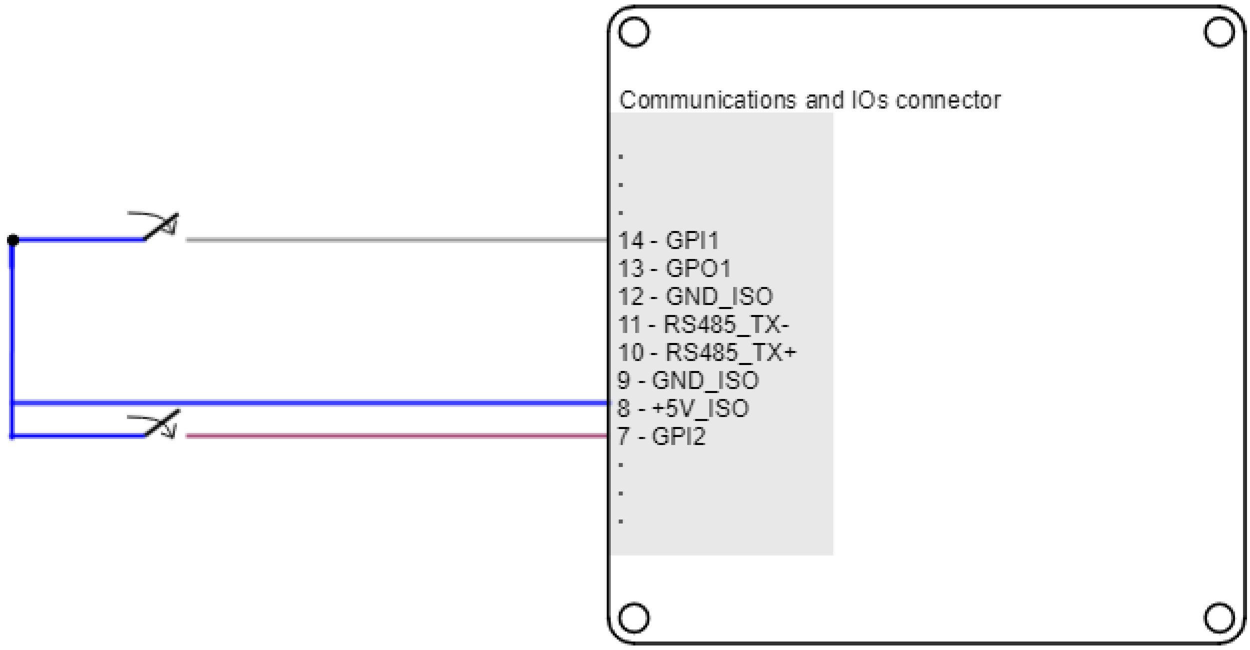
The general purpose isolated digital inputs are ready for 5 V levels. Next table show their electrical specifications.

Specification	Value
Number of inputs	5 (GPI1, GPI2, GPI3, HS_GPI1, HS_GPI2)
Type of input	Isolated. Single ended. Low-pass filtered. ESD protected
ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
Input current	0.17 mA @ 5 V; 1 mA @ 15 V
High level input voltage	3 V < V_{in} < 5 V
Low level input voltage	0 < V_{in} < 1.2 V
Input impedance	10 kΩ
1st order filter cutting frequency (-3 dB)	338 kHz
Sampling rate	1 ksps
Max delay	2.3 μs

General purpose inputs electrical equivalent circuit is the following:



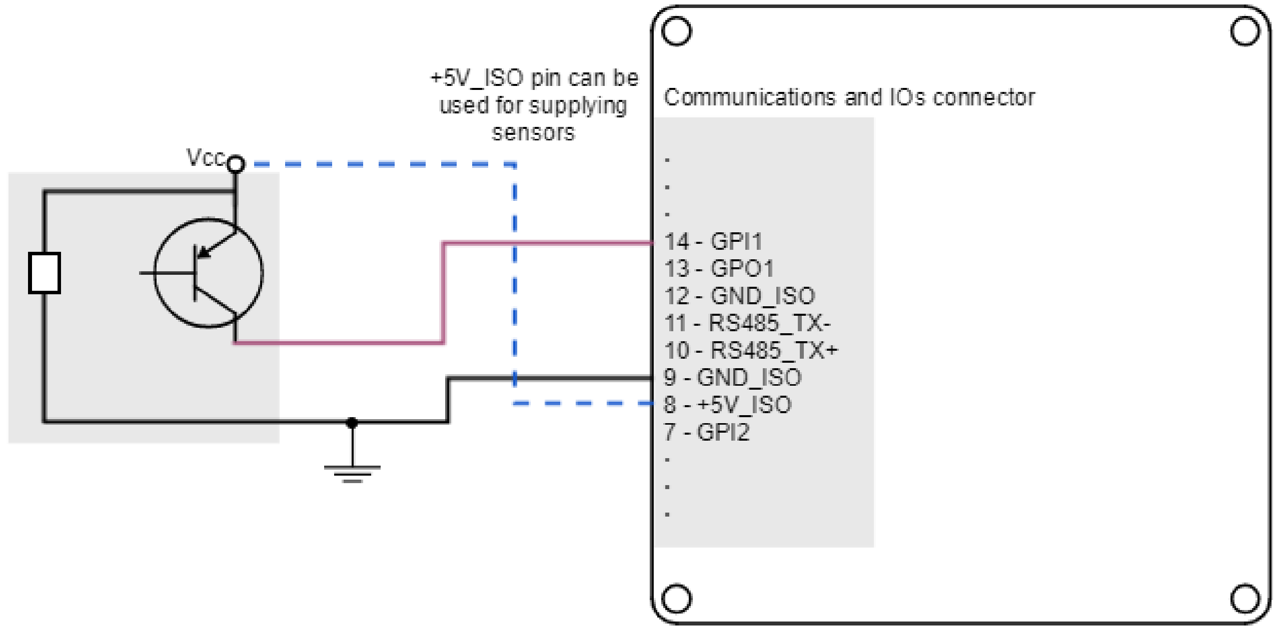
Next figure shows an example of how to connect a switch to the GPI1 and GPI2, using +5V_ISO (pin 8) pin as a supply source. Same connection could used for GPI3.

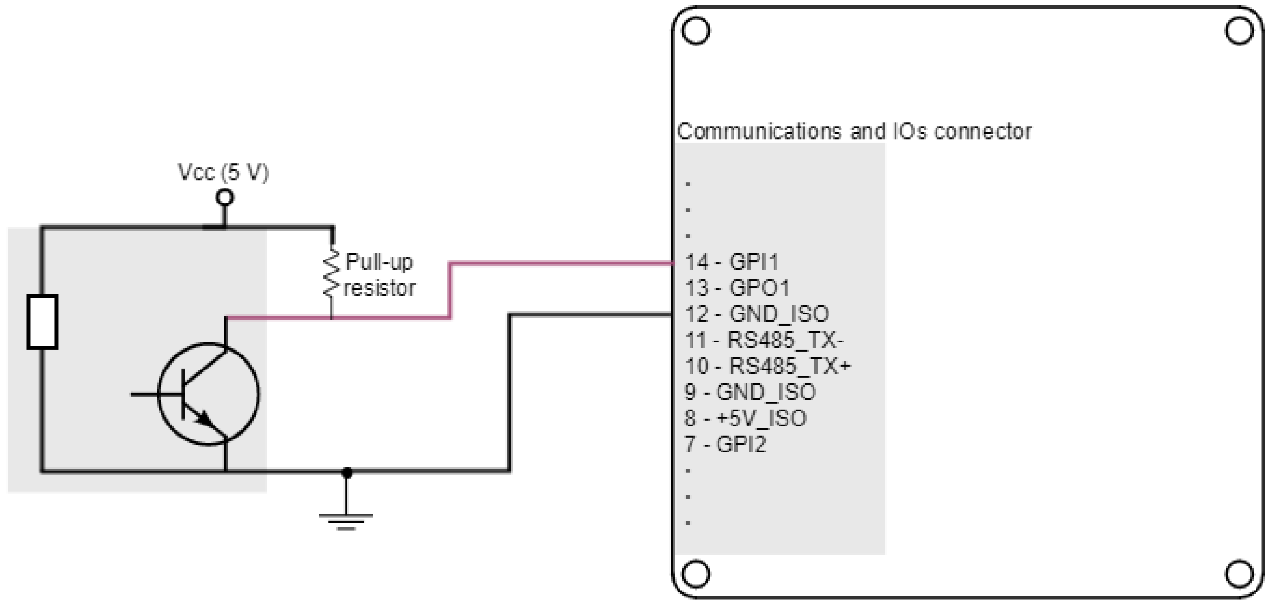


24 V inputs

To get 24 V inputs compatibility, just place a resistor of ≈ 80 kΩ in series with the input.

Titan Go 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 GPI1 (same wiring can be used for GPI2, GPI3 and HS_GPI1 and HS_GPI2). Pin 8 (+5V_ISO) can be used as a supply source.





GPI Pull-up resistors

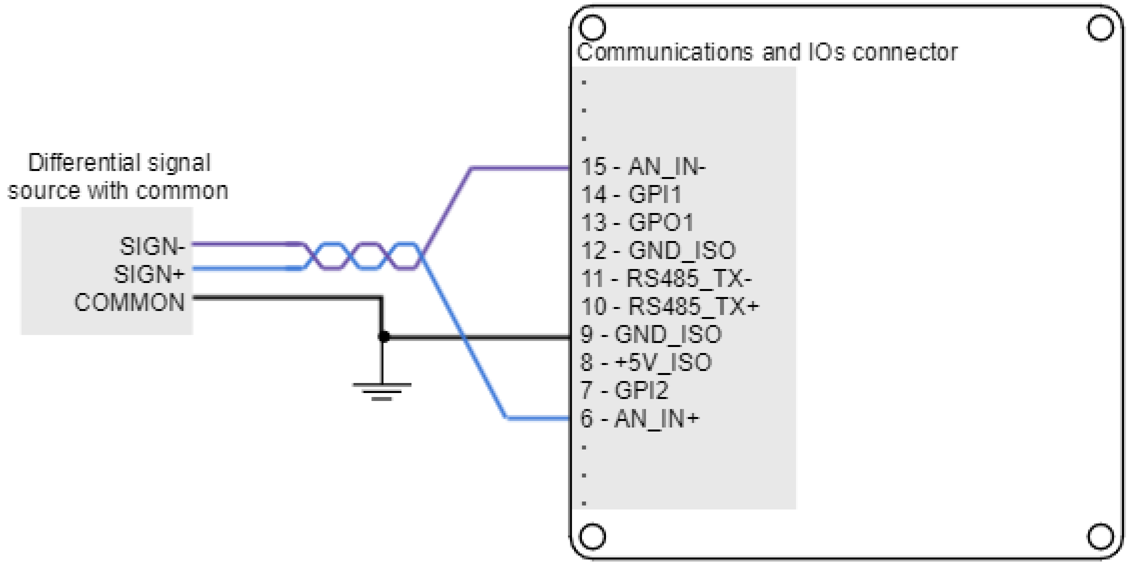
Pull-up resistors ensure the desired logic state when the sensor (transistor or relay) is in off-state.
NPN pull-up resistor value must be chosen in order to ensure ≥ 4 V at the GPI pin considering the 10 kΩ input resistance. For a sensor supply of 5 V, 1 kΩ is recommended.

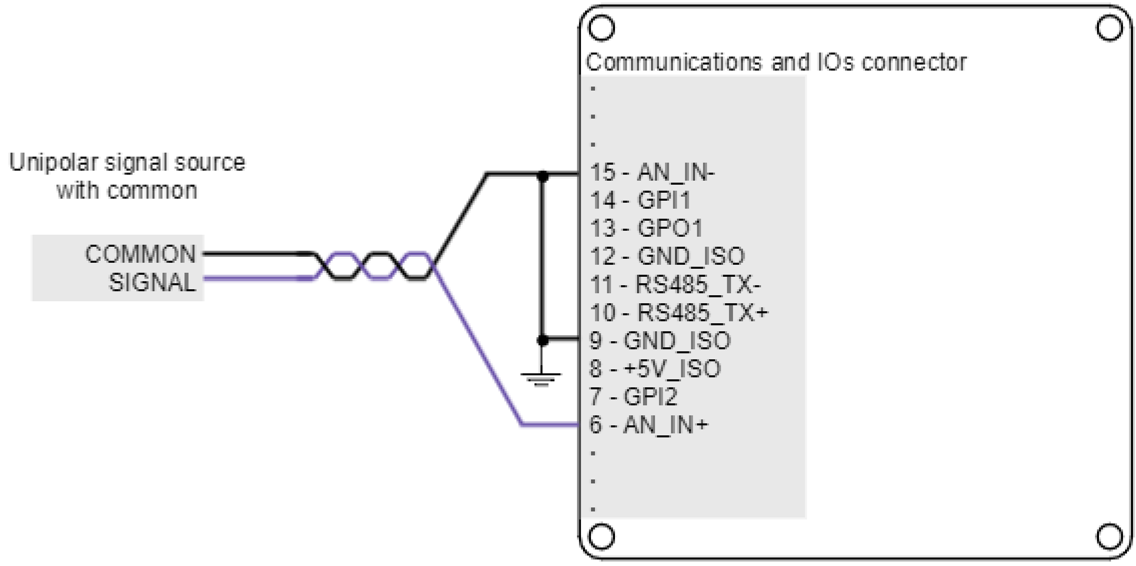
7.6.2 Analog inputs interface (AN_IN1)

Titan Go Servo Drive has one 12-bit analog input (AN_IN1), which is differential. Next table summarizes the main features of the analog input:

Specification	**Analog input 1**
Type of inputs	Isolated. Differential. ESD protected
ESD capability	± 8 kV (contact)
Analog input resolution	12 bits
Maximum operating voltage	±10 V
Maximum common mode voltage (Analog input 2)	±10 V
Maximum voltage on any pin (referred to GND)	10 V
1st order filter cutting frequency (-3dB)	116 kHz
Sampling rate (max)	10 ksps

Next figure shows how to interface differential and single ended voltage sources to the differential analog input 1. The differential analog input is typically used as a command source or feedback signal.





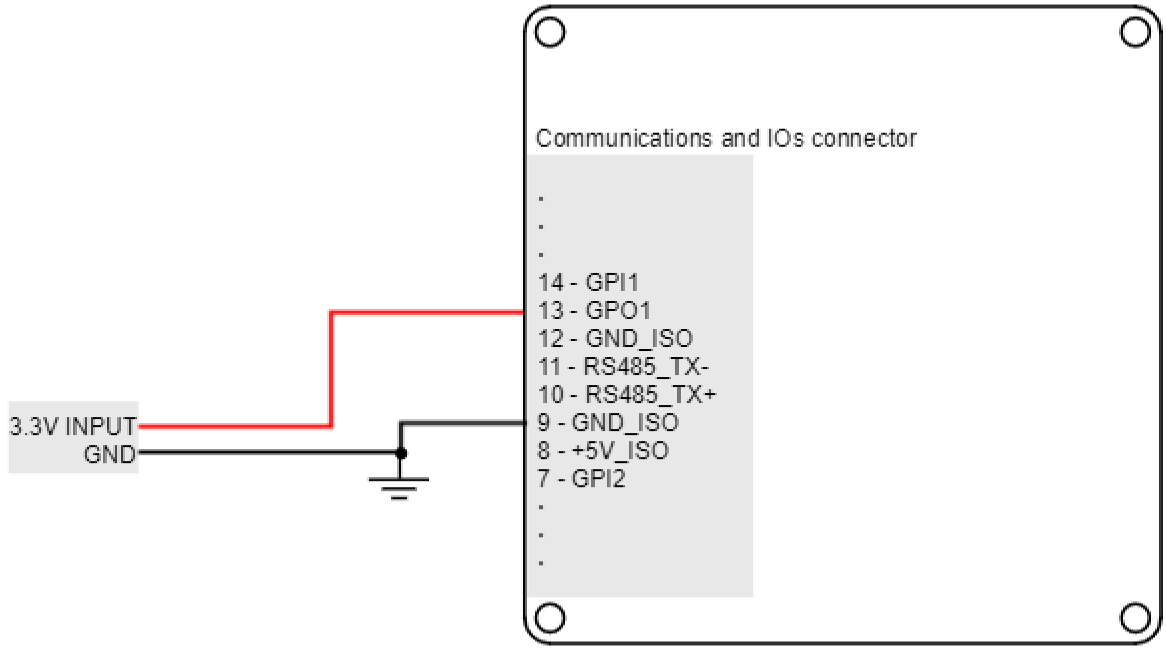
7.6.3 Digital outputs interface (GPO1)

Titan Go Servo Drive has one digital isolated output. This digital output is intended for signalling, as it is the output of a digital isolator.

Specification	**Value**
Number of outputs	1
Type of output	Isolated. Logic digital output. ESD protected.
Maximum supply output	3.3 V
Maximum sink/source current	Source: low current @ 3.3 V: 10 mA
Max working frequency	1 kHz

7.6.3.1 Wiring of 3.3 V loads

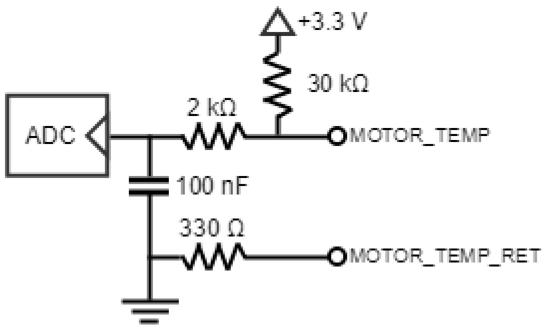
Loads that require 3.3 V as high-level voltage can be connected directly to the digital output. A wiring example for GPO1 is shown in the next figure.

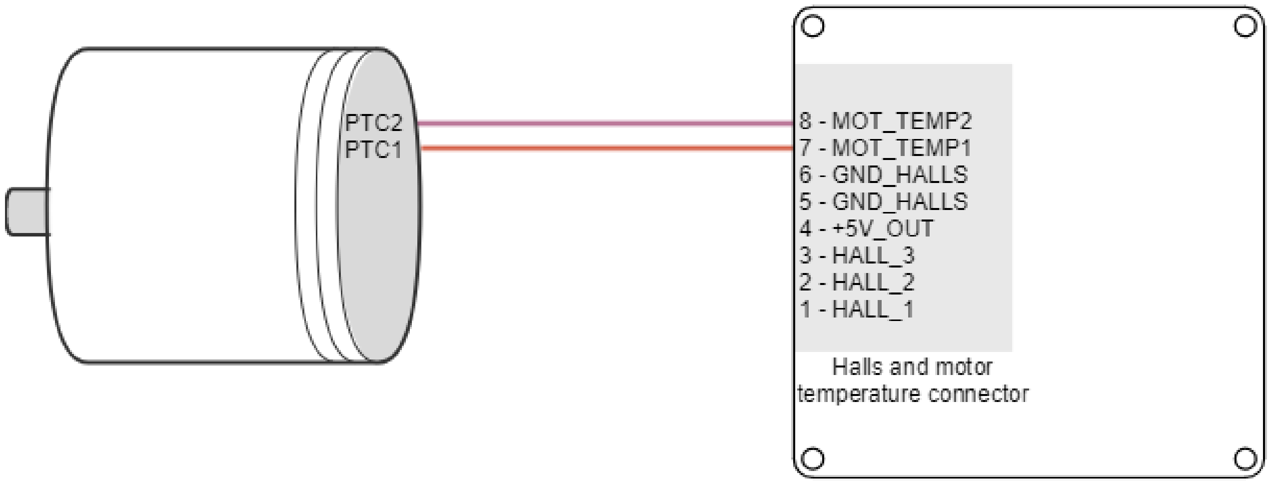


7.6.4 Motor temperature input (MOTOR_TEMP)

The Titan Go has a dedicated analog input for measuring the motor temperature, which can be found in the Halls and motor temperature connector. The motor temperature input is connected to the internal analog input 3 and allows the connection of an external temperature sensor (PTC thermistor, bimetal, NTC) to measure the motor temperature.

This analog input includes a 30 kΩ pull-up for directly connecting a NTC thermistor. Following is shown the circuit and an example of temperature sensor wiring:





Suggested PTC

The suggested NTC thermistor value is a 100 kΩ nominal resistance (@ 25 ªC) as Vishay NTC (NTCALUG01A104F).

Main specifications of the external temperature sensor input are shown in the next table:

Specification	Value
Type of input	Single ended analog 30 kΩ pull-up resistor
Mapping	Analog input 3 (AN_IN3)
1st order low-pass filter cutting frequency (-3dB)	800 Hz

7.7 Command sources

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

- Network communication interface (USB, CANopen, RS-485)
- Standalone
- Analog input (±10 V or 0-5 V)
- Step and direction
- PWM command (single and dual input mode)
- Encoder following / electronic gearing.

Analog inputs, step and direction, PWM command and encoder following / 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 or 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.

7.7.1 Network communication interface

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

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

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

For further information, see Communications section.

7.7.2 Standalone

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

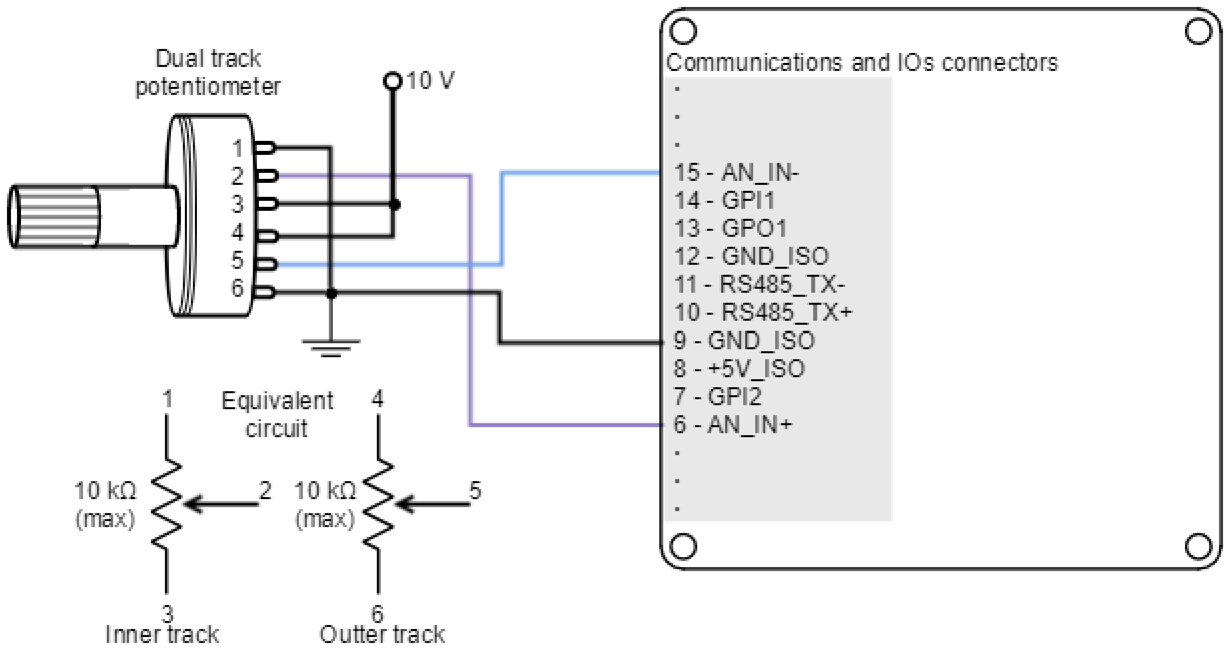
This feature can be very useful in applications such as production lines or test equipment, where repetitive movements are usual. Please refer to MotionLab documentation for further information.

7.7.3 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. Titan Go Servo Drive has a differential 12-bit analog input with +/-10 V range (AN_IN1). 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 dual track potentiometer to the differential analog input (AN_IN1).

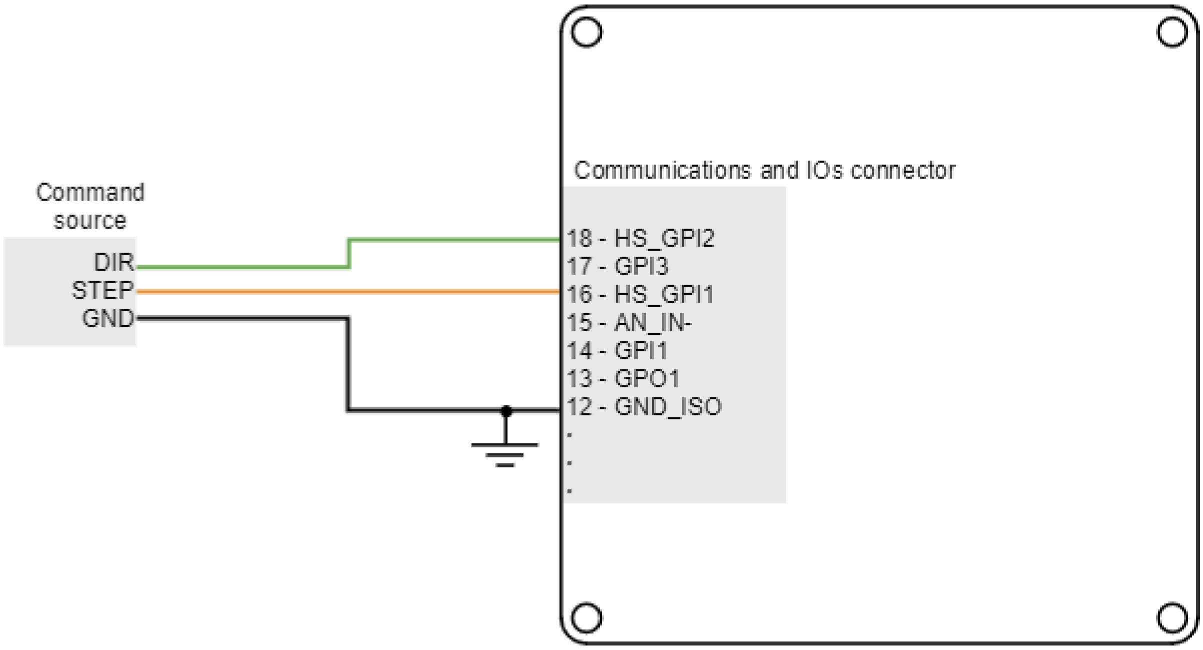
As an application example, the next picture shows how to connect a dual track potentiometer to get a ±10 V differential input.



7.7.4 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 step and direction command source to the Titan Go Servo Drive.



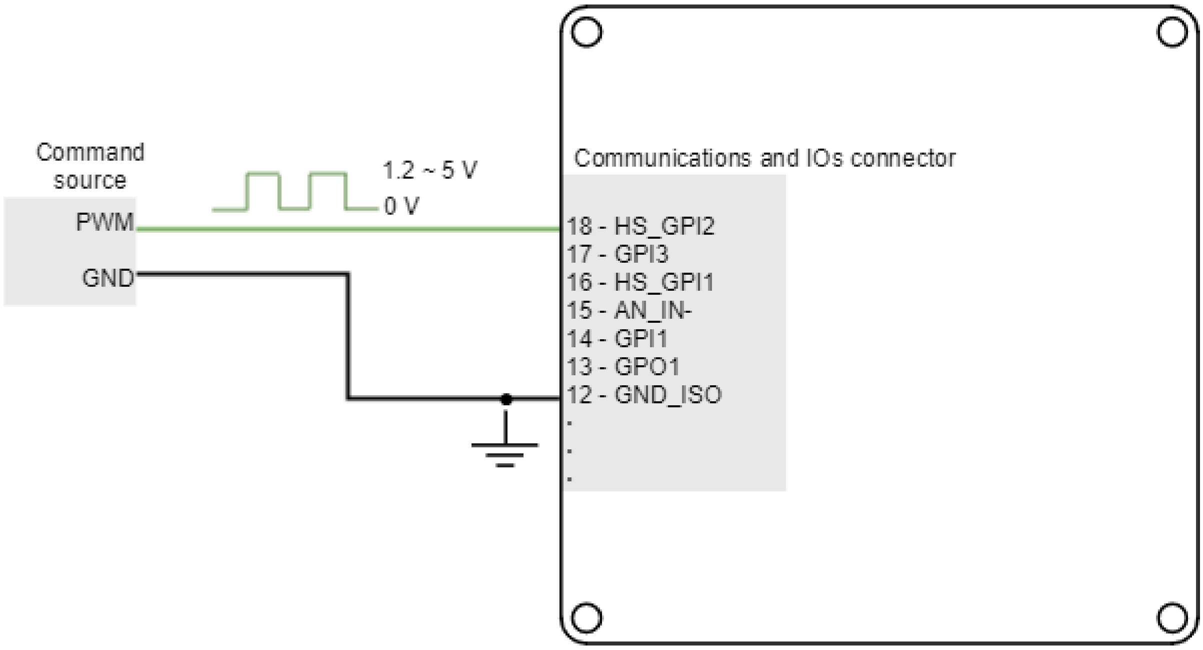
7.7.5 PWM command

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

7.7.5.1 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.



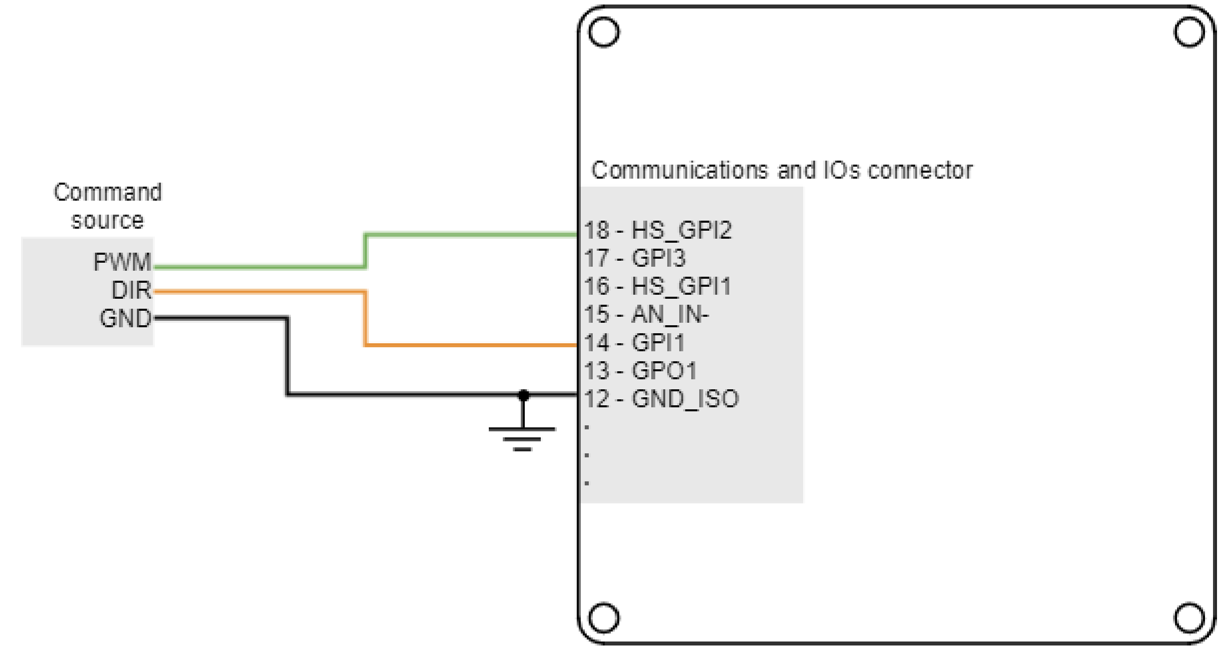
7.7.5.2 Dual input mode

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.

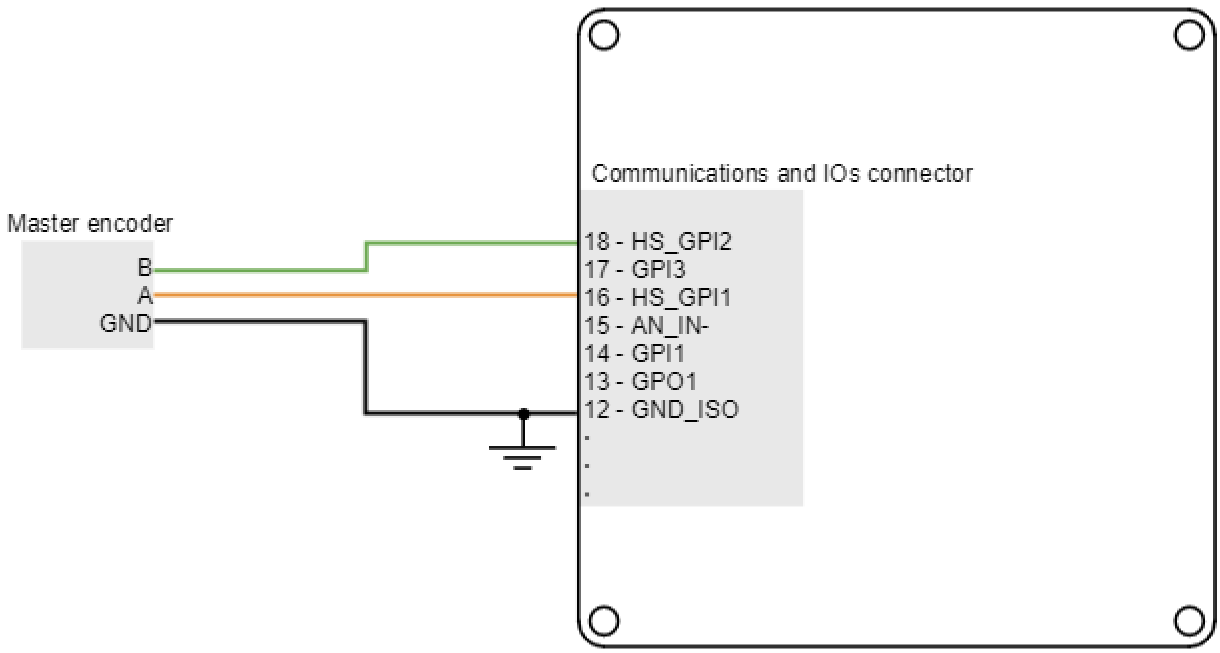
Examples of dual input mode PWM command in differential and single ended connections are shown in the next figures.



7.7.6 Encoder following or electronic gearing

Encoder following command source is used tor **drive two motors to the same position**. The encoder (or an auxiliary encoder) of the master motor is read by the Titan Go 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:



7.8 Communications

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

- USB
- Serial interface - RS485
- CANopen

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

7.8.1 USB interface

Titan Go Servo Drive supports Universal Serial Bus (USB), a standard interface for connecting peripheral devices to a host computer. The USB interface is isolated from the rest of the drive to provide extra ruggedness against noisy environments. The following table shows main USB interface specifications:

Specification	**Details**
USB version	USB 2.0 (full speed)
Data rate	Up to 12 Mbps
Recommended maximum cable length	1 meters (3 feet)
Isolation	2.5 kV_{RMS}

USB application

USB interface is recommended for configuration purposes. For noisy environments, CANopen or RS485 interfaces are strongly recommended.

7.8.1.1 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 mini USB connector is connected on Titan Go, but it is isolated from the rest of the drive.
- Do not rely on an earthed PC to provide the Titan Go Servo Drive earth connection. The drive must be earthed through a separate circuit.
- Avoid creating ground loops by using isolated power supplies.
- Make sure to separate USB shield from power protective earth. If using panel connectors, avoid metal versions where the USB shield is in contact with the metal enclosure, this may seriously reduce USB performance by coupling power noise to the weak communications ground.
- Shortest cables are always preferred.

7.8.2 RS485 interface

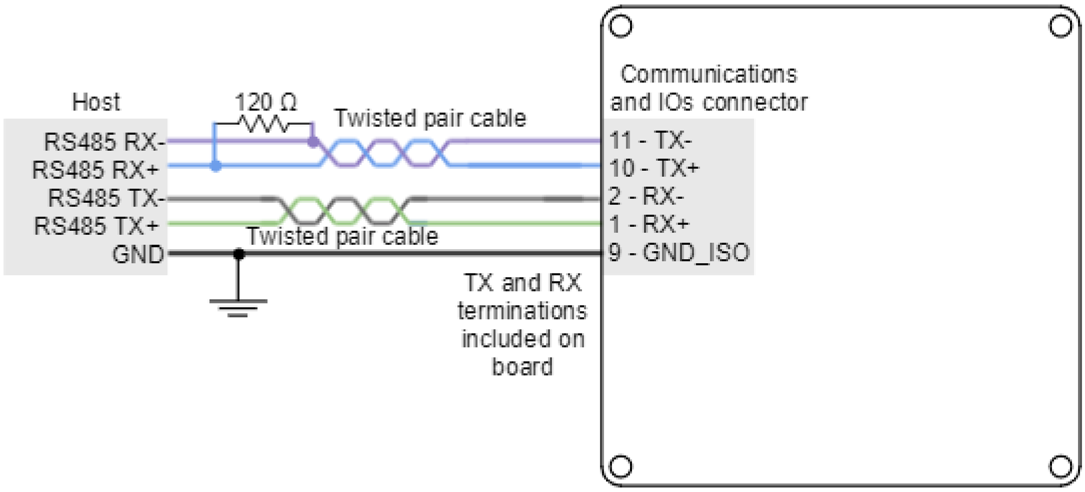
Titan Go Servo Drive supports **full duplex RS-485**. This means that independent differential lines are used for TX and RX, which cannot be connected together. **Full-duplex RS485 is fully compatible with RS422 communication.**

> **Multi-point connection**
>
> Titan Go Servo Drive RS485 interface is not intended for bus operation, since there is no collision prevention protocol implemented. However, **multiple drives can be connected to the same master using daisy chain connection**.
> Multiple drive connection with daisy chain **must be configured using Ingenia** MotionLab **suite.** For allowing multi-point communication **each servo drive must be allocated a unique node ID**, and **daisy chain option must be enabled.** Please, see UART configuration section in E-Core documentation for further information.

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

Specification	**Details**
Interface	Full duplex. Isolated (GND shared with CAN). Self-supplied (no need for external supply)
Communication distance	Up to 1200 m
Baud rate	128 kbps to 460 kbps
Daisy chain	Supported
Termination resistor	120 Ω termination resistor on RX channel

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

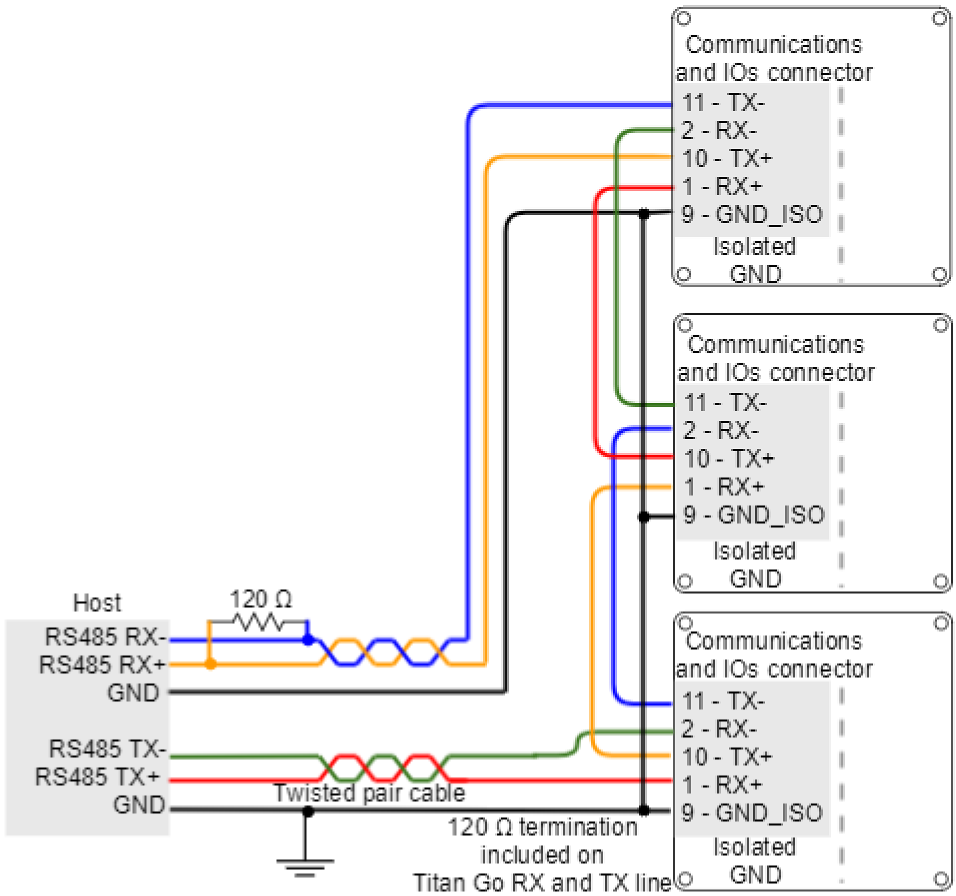


Termination resistor

The use of **termination resistors at the RX side** of each differential pair (120 Ω between RX+ and RX- of both host and slave) is essential for correct operation of the RS485 communication. **For long cable distances (> 10 m) a termination in the TX side** is also recommended.
Titan Go Servo Drive includes TX and RX termination resistors on board. They can be activated/ deactivated with the switches available near the connector. Another 120 Ω termination resistor should be placed at the end of Titan Go TX line (RX of the host). Suggested termination resistor: Xicon 271-120-RC.

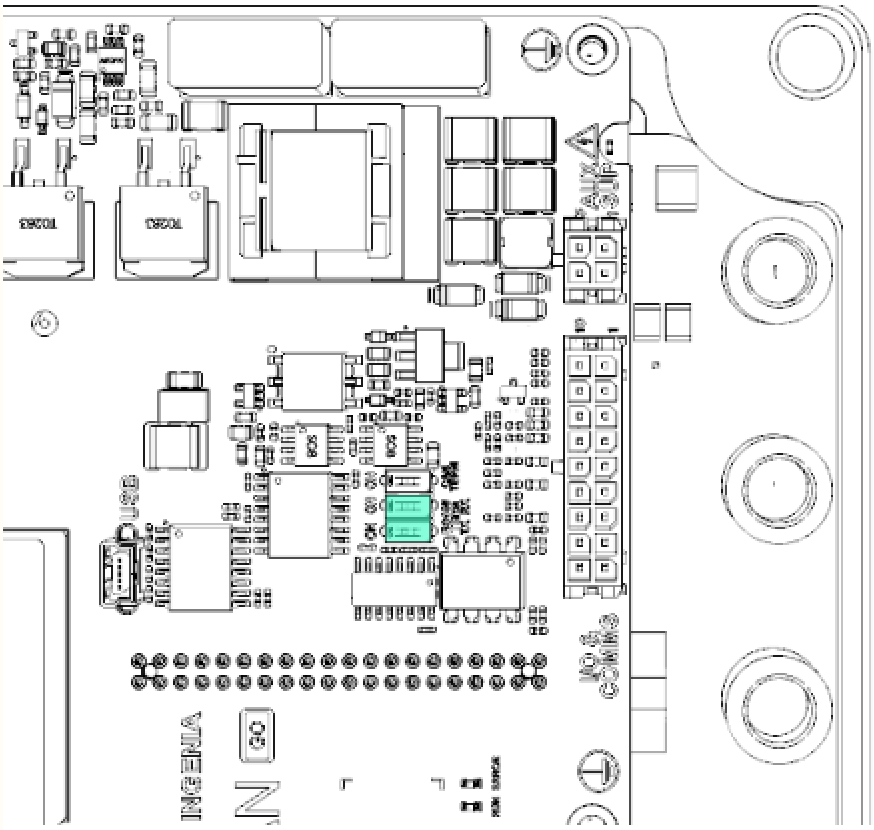
7.8.2.1 Multi-point connection using daisy chain

Daisy chain connection is a multi-point network topology based on connecting multiple terminals in a ring. The wiring consists on connecting the TX terminals of each device to the RX terminals of the next device. An example of daisy chain wiring of multiple Titan Go is shown in the next figure.



Termination resistor for daisy chain

In daisy chain connection, **termination resistors are required in each link**. For short distances, a 120 Ω termination resistor in the RX side is required. For long distances (> 10 m) it is required in RX and TX sides.
Titan Go Servo Drive includes TX and RX termination resistors on board. They can be activated/ deactivated with the switches available near the connector.



7.8.3 CANopen interface

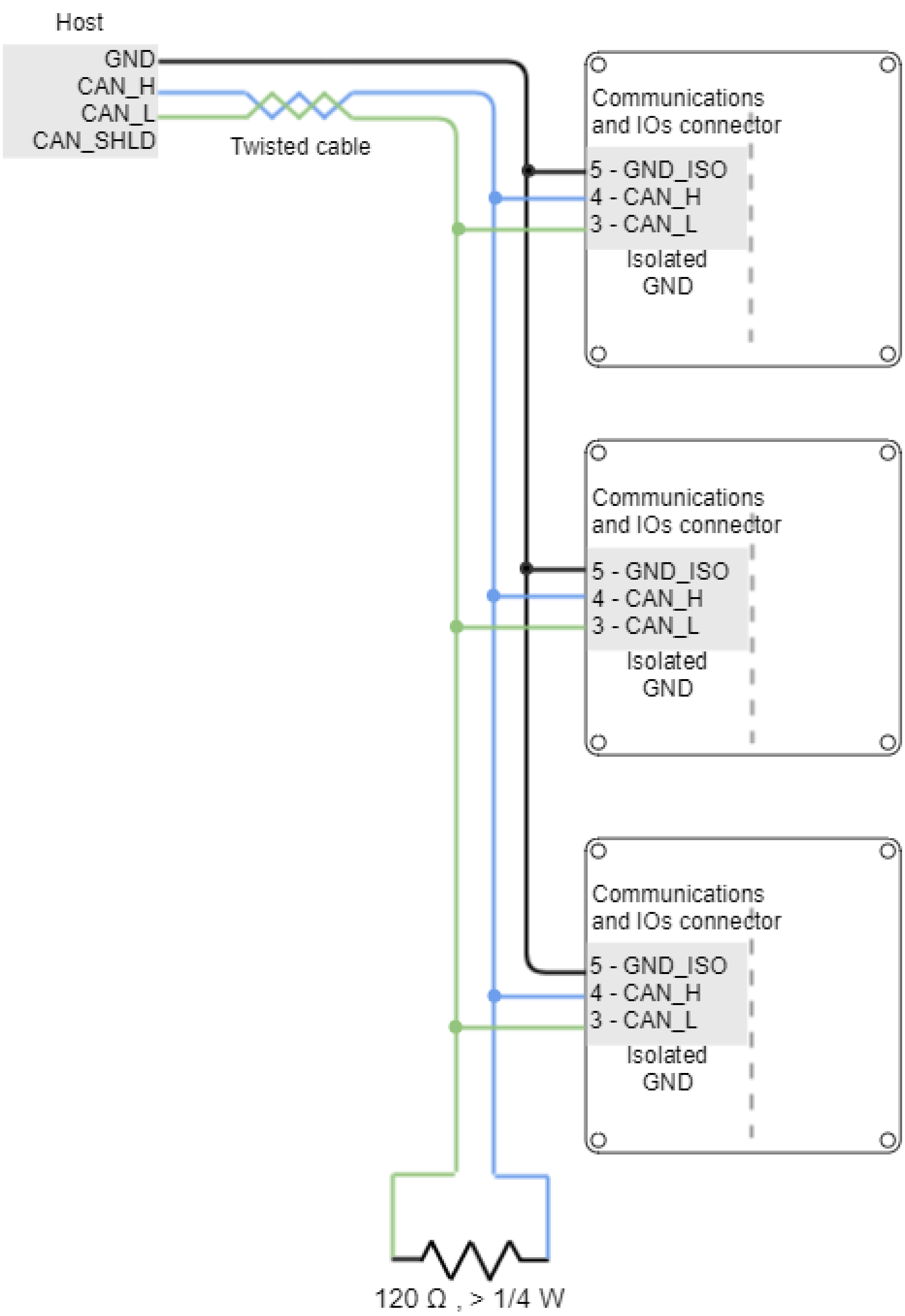
Titan Go Servo Drive provides access to the CANopen interface, a multi-terminal communication protocol based on CAN (Controller Area Network) bus. Titan Go CAN interface is isolated, and self-supplied. Main physical specifications are shown in the next table:

Specification	Details
Interface	Isolated (GND shared with RS-485). Self-supplied (no need for external supply)
Baud rate	From 125 kbps to 1 Mbps (default value)
Maximum number of nodes	64
Common mode voltage	Up to 36 V
Termination resistor	120 Ω on board (externally connect CAN_TERM to CAN_L to enable)

ⓘ **Drive ID**

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

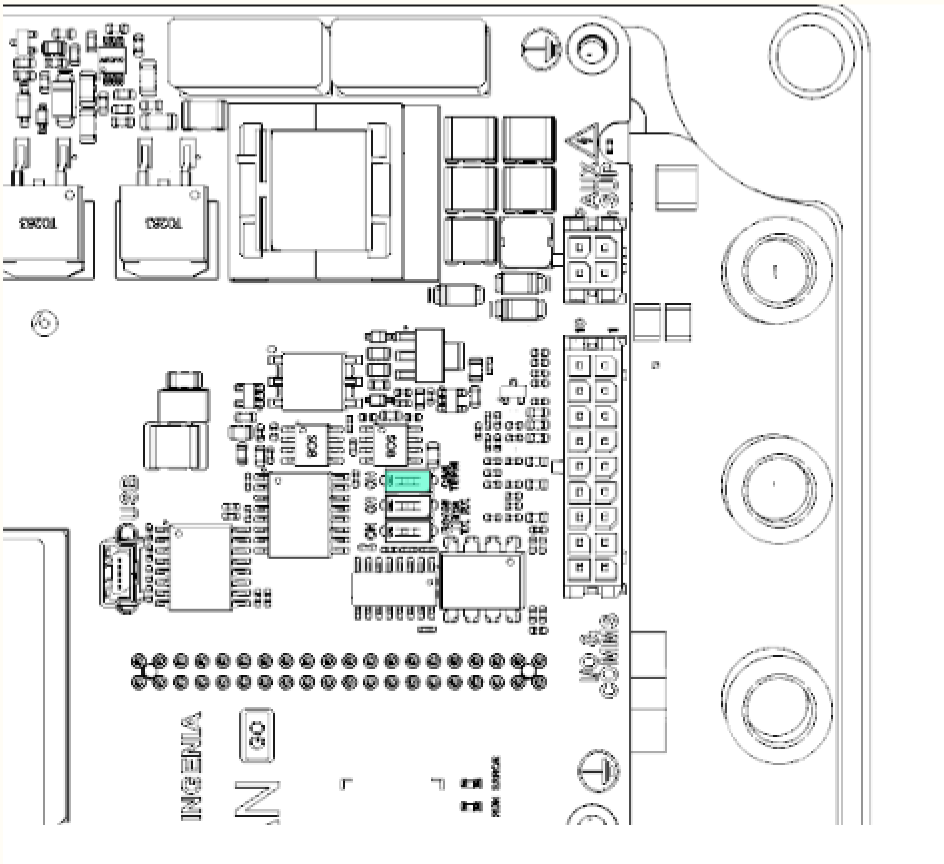
An example of CAN wiring is shown in the next figure.



Termination resistor

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

Titan Go Servo Drive includes a termination resistor on board. It can be activated/deactivated with the switch available near the connector.



7.8.3.1 CAN interface for PC

The Ingenia MotionLab suite is able to communicate with the Titan Go Servo Drive through CANopen interface. For this purpose, a CAN transceiver for PC is required. Motion Lab is compatible with the following CAN transceivers: Kvaser, Peak-System, IXXAT, Vector and Lawicel.

Some recommended CAN transceivers are shown below:

Manufacturer	Part Number	Image	Description
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.

Manufacturer	Part Number	Image	Description
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.

7.8.3.2 CAN wiring recommendations

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

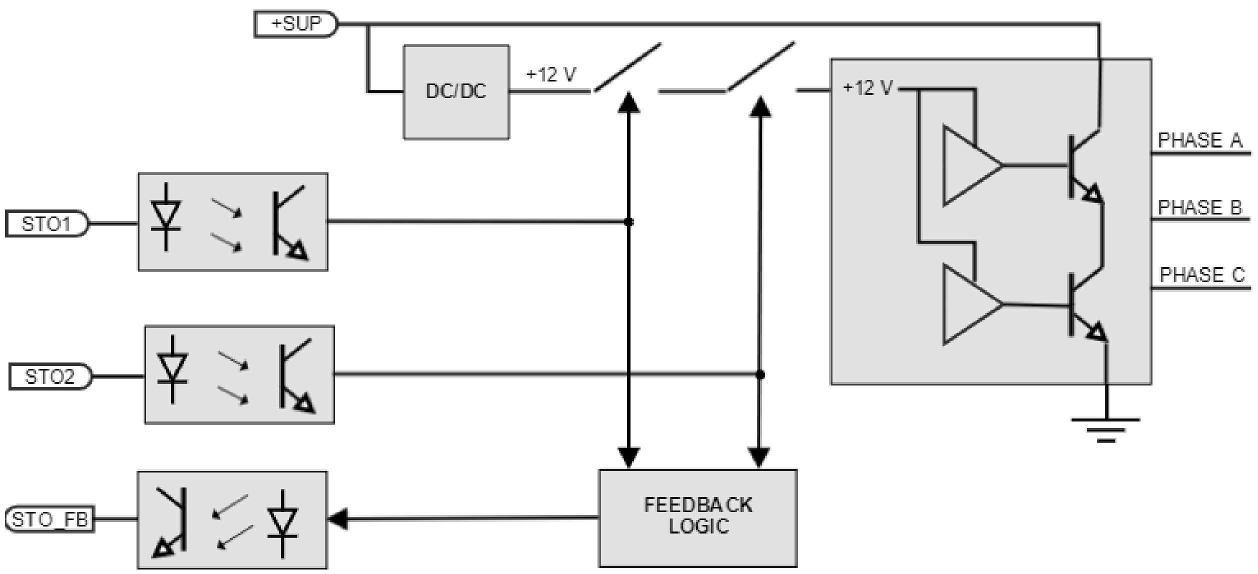
7.9 Safe Torque Off (STO)

The STO is a hardware safety system that prevents motor torque in an emergency event. When STO is activated, the power stage is disabled automatically (no mater what control or firmware does), and the motor shaft will slow down until it stops under its own inertia and frictional forces.

> **Do not leave STO unconnected**
>
> If STO is not used, both inputs STO1 and STO2 must be enabled. Otherwise it will be impossible to apply torque to the motor.
> Tip: In order to enable the inputs it is suggested to connect STO_COMMON to GND of connector P1 and connect both STO1 and STO2 to 24V_OUT of connector P1.

The Titan Go STO works with negative logic, deactivating the power stage by default. **In order to activate the power stage**, and therefore allow the motor operation, **two differential inputs must energized**. These inputs activate two optocouplers that enable the Titan Go power stage operation. On the contrary, **if the STO inputs are not energized, the transistors of the power stage are turned off** and a STO fault is notified. During this state, no torque will be applied to the motor no matter configuration, or state of a command source. This will slow down the motor shaft until it stops under its own inertia and frictional forces. This input should not be confused with a digital input configured as enable input, because enable input is firmware controlled and does not guarantee intrinsic safety as it can be reconfigured by a user.

The following diagram shows a simplified schematic of the STO circuit.



The Titan Go STO have been designed to be compliant with Safety Integrity Level 3 (SIL 3) according to IEC 61800-5-2. In order to fulfill the requirements, the STO reliability has been increased by means of the following charateristics:

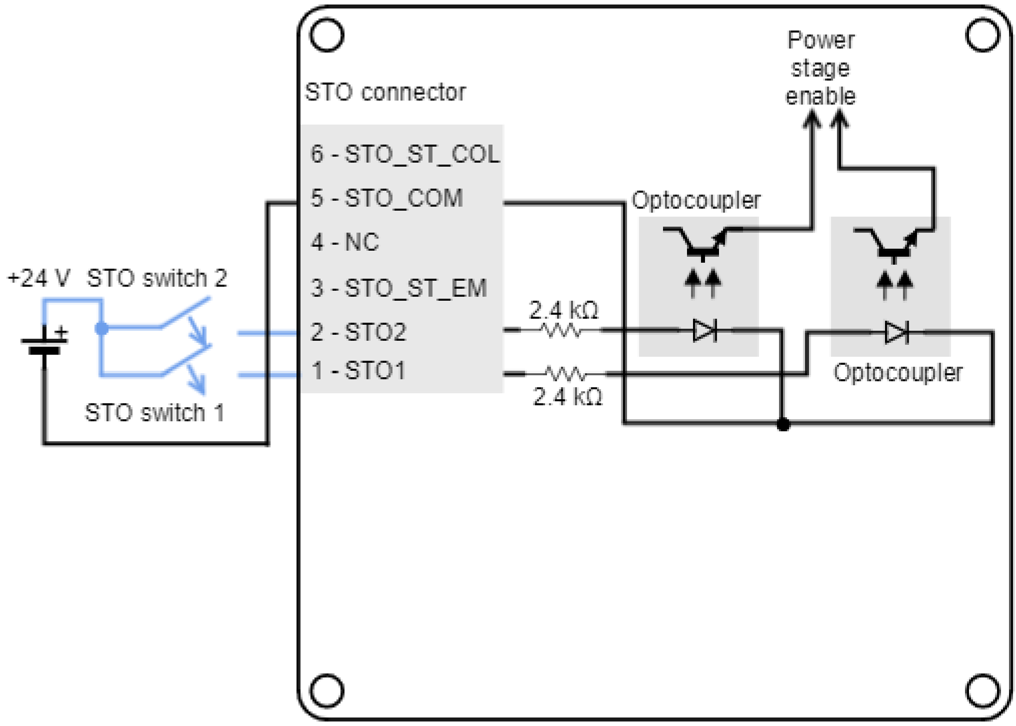
- Two fully independent STO channels
- STO Feedback output for external diagnostics
- Detection of abnormal STO operation

7.9.1 Fully independent STO channels

The power stage logic is supplied by two cascaded MOSFET transistors. Each transistor is activated by an independent isolated STO input. The design guarantees that **a single failure will not accidentally activate the power stage**.

> **STO firmware notification**
>
> An STO stop is notified to the control DSP and creates a fault that can be read externally, however its performance is totally independent from control or firmware. When the STO is not connected it is virtually impossible to apply power to the drive.

STO inputs have an input voltage of +24 V. Next figure shows how to connect the STO inputs with an external power supply.

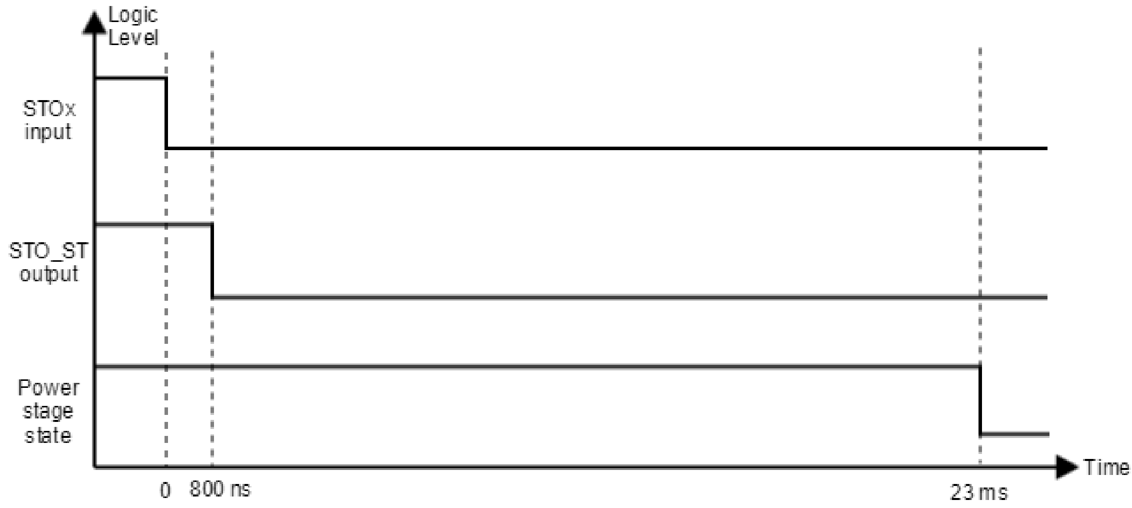


7.9.2 STO status feedback output

The STO also includes a status feedback output. It is automatically controlled by the internal circuits, and the output is normally active, providing a closed contact. **When one of the STO inputs becomes de-energized (low-level), the STO_ST becomes low-state** too.

The objective of the STO_ST is to allow external diagnostics of the STO circuit, allowing an increase of the system reliability. A common-practice in the diagnostics is to delay the stop of the power stage from the deactivation of the STO_FB and from the deactivation of the STO inputs. This way, **short pulses can be applied for testing the STO circuit without stopping the system operation**.

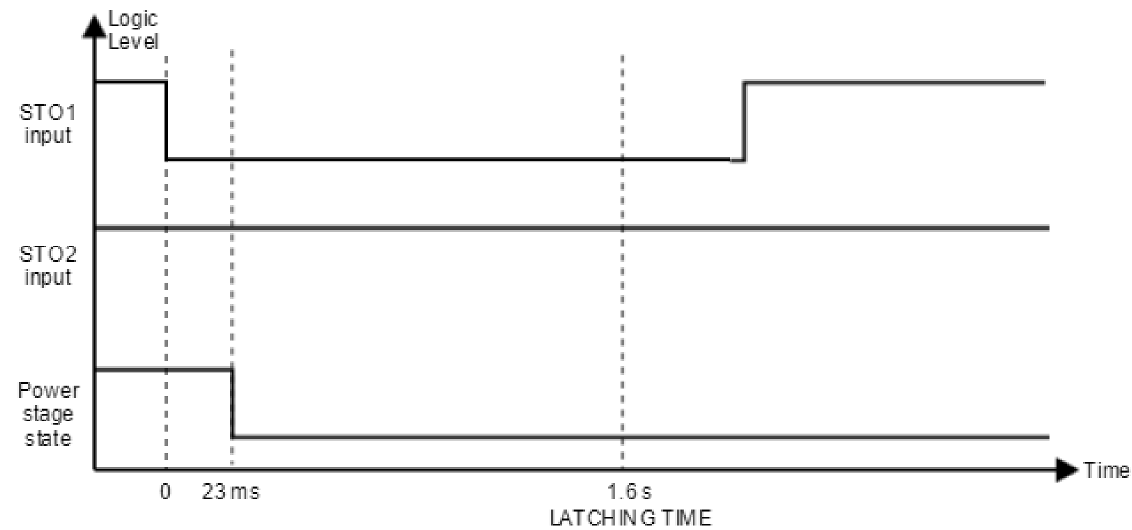
The following figure shows the timings corresponding to the STO:



7.9.3 STO abnormal operation

Abnormal operation of the STO is when only one of the channels is energised. In case that only one channel is energised for more than 1.6 s, a dangerous failure in the system is considered and the STO is activated in latching mode. The fault cannot be reset until a supply reset is performed.

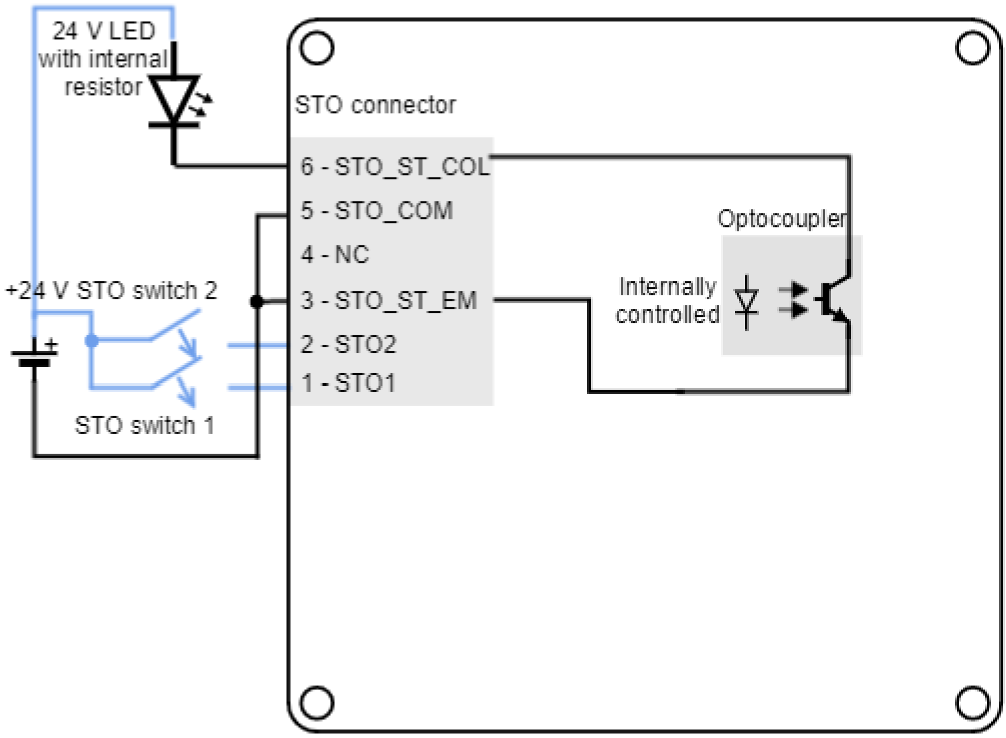
The following figure shows an example of the STO abnormal operation.



The following table shows a sumary of the STO performance.

Mode	Status	STO 1 input	STO 2 input	Power stage state	STO_FB	Drive function
Normal operation	STO ACTIVE (No torque to the motor)	0	0	Disabled	0	Drive cannot start or provide power to the motor. STO trip reported to the DSP and to STO_FB. This is intended safe torque off with dual channel operation.
	STO INACTIVE (Ready to run)	1	1	Enabled	1	Drive is enabled to run under firmware control. The drive can supply power to the motor.
Diagnostic	STO ACTIVE PULSE (1 ms < t < 23 ms)	x	0	Enabled	0	A short STO ACTIVE ("0") pulse does not stop the motor operation. However, it activates the STO FEEDBACK. It can be used for performing system diagnosis and increasing system reliability.
	STO ACTIVE PULSE (1 ms < t < 23 ms)	0	x	Enabled	0	
Abnormal operation	Abnormal STO ACTIVE	0	1	Disabled	0	Drive cannot start or provide power to the motor. STO trip reported to MCU. If this persists for > 2.3 s the STO will lock in FAULT state. To reset this fault a power cycle is needed.
	Abnormal STO ACTIVE	1	0	Disabled	0	
	STO FAULT	x	x	Disabled (latched)	AND (STO1, STO2)	After > 2.3 s of abnormal STO active the driver will stay latched in this state untill power cycle.

Finally an example to use the STO_ST to drive a signalling LED (transistor optocoupler tolerant up to 80 V and 50 mA):


24 V LED
with internal
resistor
STO connector
6 - STO_ST_COL
5 - STO_COM
4 - NC
3 - STO_ST_EM
2 - STO2
1 - STO1
Optocoupler
Internally
controlled
+24 V STO switch 2
+
STO switch 1

8 Dimensions and assembly

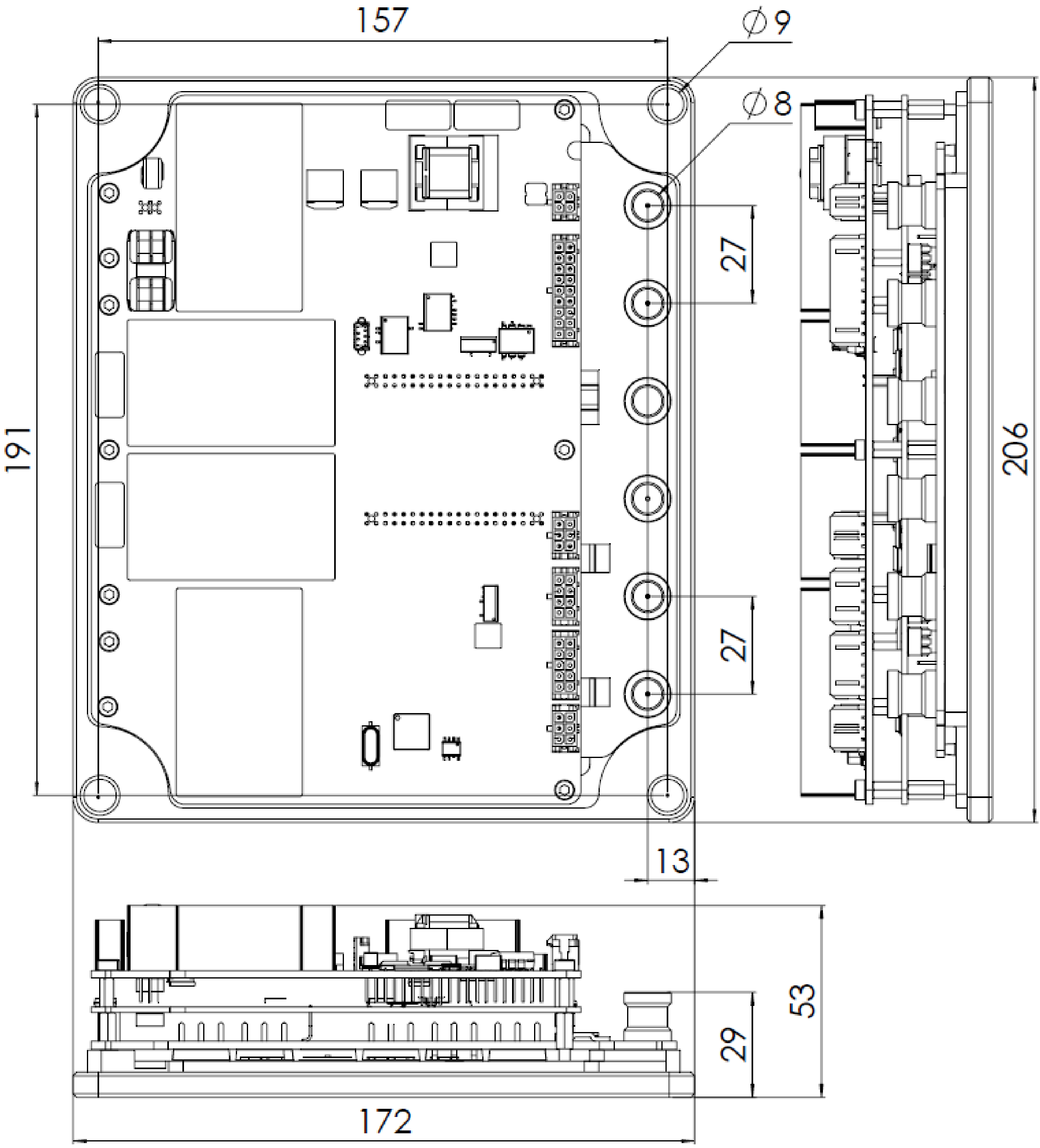
The Titan Go Servo Drive have a **206 mm x 172 mm footprint**, **55 mm height** and 4 x Ø 9 mm holes for **M8 screws** mounting.

Thermal dissipation required

To reach its power specifications, Titan Go must be mounted over a **heatsink**, and a thermal interface material must be placed and compressed in between to ensure a good contact. See below .

8.1 Titan Go Dimensions

Following are shown the Titan GO dimensions. For further details download the 3D model.



All dimensions are in **mm**. All tolerances **≤ ±0.2 mm**.

8.2 Assembly Instructions

The assembly of the plate to a cooling surface is essential to achieve desired performance. Due to the dimensions of the plate, it is essential that the thermal pad is thick and soft enough to compensate the flexing during assembly. Thermal grease is not recommended since an imperfect application will leave air gaps wich result in poor heat transfer. Next are some thermal interface materials suitable for the Titan.

8.2.1 Heatsinks or cooling plates

In order to choose the cooling needs of the Titan, please see the thermal calculations in Product Description page.

Given the power ratings of the Titan, typically passive cooling heatsinks will not be enough for continouous operation. Forced air or water cooling solutions are suggested. See some examples next:

Manufacturer	Type	Part Number	Thermal resistance	Dimensions	Image
Wakefield-Vette	Liquid cooling plate with exposed copper	120459	0.007°C/W at 1.4 GPM	381.0 mm x 127.0 mm x 15.2 mm (excluding heat exchanger and pump)	
Fischer Elektronik	Heatsink with cooling fan at 24V	LA 11 200 24	0.055°C/W	240 mm x 200 mm x 83 mm	

You can have the highest performance cooling plate and not be capable of cooling the Titan if the assembly is incorrect!
Please use appropriate thermal interface materials and follow the assembly instructions to achieve an excellent heat transfer. See below .

8.2.2 Thermal interface material

Thermal interface materials for a cooling plate with a big surface should be **tacky and soft** to prevent the formation of air bubbles. Also thickness should be enough to compensate for the flexion of the plate while being compressed, 0.5 mm is typically enough for this purpose.

Please note that thin "high performance" materials that look promising on the datasheet may end up with poor heat transfer. With thin materials the pressure is only applied near the screws and air bubbles are formed, decreasing the heat transfer dramatically.

Manufacturer	Part Number and description	Thickness before compression	Thermal conductivity	Estimated thermal resistance plate to heatsink
Laird Technologies	A15896-02 TFLEX 720 9X9"	0.50 mm	5.0 W/m·K	0.003 K/W
Laird Technologies	A15896-04 TFLEX 740 9X9	1.00 mm	5.0 W/m·K	0.005 K/W

Manufacturer	Part Number and description	Thickness before compression	Thermal conductivity	Estimated thermal resistance plate to heatsink
Bergquist	GPHC5.0-0.020-02-0816	0.51 mm	5.0 W/m·K	0.003 K/W
Bergquist	GPHC5.0-0.040-02-0816	1.02 mm	5.0 W/m·K	0.005 K/W
t-Global Technology	H48-6A-320-320-0.5-1A	0.50 mm	4.0 W/m·K	0.004 K/W
t-Global Technology	H48-6A-320-320-1.0-1A Adhesive one side	1.02 mm	4.0 W/m·K	0.006 K/W

8.2.3 Screw assembly

Screw the plate evenly. Apply a torque that guarantees pressure on all the surface and does not bend the aluminum plate. Recommended screw size is M8. Use stainless steel good quality screws. The maximum screw torque is 9 Nm. **Higher torque will not result in better heat transfer** as the plate would bend and pressure would not be well applied.

Spring washers are a must in order to guarantee long term pressure.

M8 screw	
Description	M8 allen screw, 20 mm length
Image	
Part number	RS-Pro 232-8344
Distributor codes	RS 232-8344
Crinkle washer	

Description	M8 stainless steel crinkle washer
Image	
Part number	Duratool D00829
Distributor codes	Farnell 1614006

9 Application Software

9.1 Configuration

To connect, configure, tune your motor or upgrade the firmware of the Titan Go, install Ingenia MotionLab 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 Titan Go and develop standalone or multiaxis systems, you can use the multi-platform library MCLIB**.**

9.3 Arduino

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

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

10 Service

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

INGENIA-CAT S.L.

C/ ÁVILA 124, 2ºB

08018 BARCELONA

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