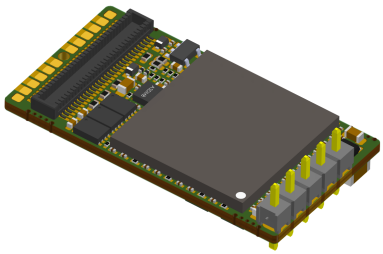
Denali NET - Product Manual - Preliminary



Edition 06/11/2021

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

INGENIA-CAT S.L.

AVILA 124

08018 BARCELONA

INGENIA
passion for motion

1. Table of Contents

2. General Information

2.1. Manual revision history

Revision	Release Date	Changes	PDF
v1	09-jun-2021	Initial version	

For the most up to date information use the online Product manual.

2.2. Disclaimers and limitations of liability

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2.3. Contact

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3. Safety Information

3.1. For your safety

The instructions set out below must be **read carefully prior to the initial commissioning or installation** in order to raise awareness of potential risks and hazards, and to prevent injury to personnel and/or damage to property.

To ensure safety when operating this servo drive, it is mandatory to follow the procedures included in this manual. The information provided is intended to protect users and their working area when using the device, as well as other hardware that may be connected to it.

3.2. Warnings

Electric servo drives are dangerous: The following statements should be considered to avoid serious injury to individuals and/or damage to the equipment:

- Do not touch the power terminals of the device (supply and phases) as they can carry dangerously high voltages > 50 V.
- Never connect or disconnect the device while the power supply is ON to prevent danger to personnel, the formation of electric arcs, or unwanted electrical contacts.
- Disconnect the drive from all power sources before proceeding with any wiring change.
- The surface of the device may exceed 100 °C during operation and may cause severe burns to direct touch.
- After turning OFF and disconnecting all power sources from the equipment, wait at least 10 seconds before touching any parts of the controller, as it can remain electrically charged or hot.

3.3. Precautions

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

- Always comply with the connection conditions and technical specifications. Especially regarding wire cross-section and grounding.
- Some components become electrically charged during and after operation.
- The power supply connected to this controller should comply with the parameters specified in this manual.
- When connecting this 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. An 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 drive, check that all safety precautions have been followed, as well as the installation procedures.

3.4. *Pour votre sécurité*

*Les instructions ci-dessous **doivent être lues attentivement avant la mise en service ou l'installation initiale** afin de sensibiliser aux risques et dangers potentiels et de prévenir les blessures aux personnes et/ou les dommages aux biens.*

Pour garantir la sécurité lors de l'utilisation de ce servomoteur, il est obligatoire de suivre les procédures incluses dans ce manuel. Les informations fournies sont destinées à protéger les utilisateurs et leur zone de travail lors de l'utilisation de l'appareil, ainsi que les autres matériels qui peuvent y être connectés.

3.4.1. *Avertissements*

***Les servo-entraînements électriques sont dangereux** : Les déclarations suivantes doivent être prises en compte pour éviter des blessures graves aux personnes et/ou des dommages à l'équipement :*

- *Ne pas toucher les bornes d'alimentation de l'appareil (alimentation et phases) car elles peuvent véhiculer des tensions dangereusement élevées > 50 V.*
- *Ne jamais connecter ou déconnecter l'appareil lorsque l'alimentation est en marche afin d'éviter tout danger pour le personnel, la formation d'arcs électriques ou de contacts électriques indésirables.*
- *Déconnectez l'appareil de toutes les sources d'alimentation avant de procéder à tout changement de câblage.*
- *La surface de l'appareil peut dépasser 100 °C pendant le fonctionnement et peut causer de graves brûlures au contact direct.*
- *Après avoir éteint et déconnecté toutes les sources d'alimentation de l'appareil, attendez au moins 10 secondes avant de toucher une partie quelconque de l'appareil, car il peut rester chargé électriquement ou être chaud.*

3.4.2. *Précautions*

Les déclarations suivantes doivent être prises en compte pour éviter des blessures graves aux personnes qui effectuent les procédures et/ou des dommages à l'équipement :

- *Respectez toujours les conditions de connexion et les spécifications techniques. En particulier en ce qui concerne la section des fils et la mise à la terre.*
- *Certains composants se chargent électriquement pendant et après le fonctionnement.*
- *L'alimentation électrique connectée à ce contrôleur doit être conforme aux paramètres spécifiés dans ce manuel.*
- *Lorsque vous connectez ce variateur à une source d'alimentation approuvée, faites-le par une ligne séparée de toute tension dangereuse éventuelle, en utilisant l'isolation nécessaire conformément aux normes de sécurité.*
- *Les équipements de control de mouvement à haute performance peuvent se déplacer rapidement avec des forces très élevées. Un mouvement inattendu peut se produire, notamment lors de la mise en service du produit. Restez à l'écart de toute machine opérationnelle et ne la touchez jamais pendant qu'elle fonctionne.*
- *N'effectuez aucune connexion à un circuit interne. Seules les connexions à des connecteurs désignés sont autorisées.*
- *Tous les travaux d'entretien et de maintenance doivent être effectués par un personnel qualifié.*
- *Avant de mettre le le contrôleur en marche, vérifiez que toutes les précautions de sécurité ont été prises, ainsi que les procédures d'installation.*

4. Product Description

Denali NET is a mid power, highly integrated, digital servo drive intended to be plugged or soldered to an application-specific daughter board. The drive features best-in-class energy efficiency thanks to its state of the art power stage, and can be easily configured with Ingenia's free software **MotionLab 3**.

Denali NET is enabled with **EtherCAT** and **CANopen** communications.

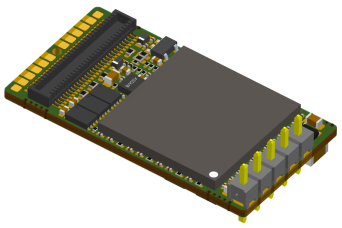
Main features:

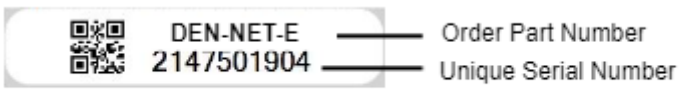
- Ultra-small footprint
- 48 V_{DC}, 5 A continuous
- Up to TBD % efficiency
- Up to 50 kHz current loop, 25 kHz servo loops
- 25 kHz ~ 50 kHz PWM frequency
- 16 bit ADC
- Supports Halls, Quadrature encoder, SSI and Dual BiSS-C
- Up to 4 simultaneous feedback sources
- Full voltage, current and temperature protections

Typical applications:

- Collaborative robot joints & end effectors
- Robotic exoskeletons & wearable robots
- Medical aplications
- UAVs
- Low inductance motors
- Lab equipment

4.1. Part numbering

Product	Ordering part number	Status	Image
Denali NET EtherCAT Pluggable servo drive with with EtherCAT communication.	DEN-NET-E	DESIGN	
Denali NET CANopen Pluggable servo drive with with CANopen communication.	DEN-NET-C	DESIGN	

General Label Identification


4.2. Specifications

4.2.1. Electrical and Power Specifications

Minimum DC bus supply voltage	5 V_{DC}
Maximum DC bus supply voltage	60 V_{DC} (continuous)
Recommended power supply voltage range	6 V_{DC} ~ 48 V_{DC} ⓘ This voltage range ensures a safety margin including power supply tolerances and regulation during acceleration and braking.
Internal drive DC bus capacitance	5 µF ± 30% ⓘ Note that DEN-NET uses ceramic capacitors. The capacitance value varies with DC bias and temperature.
Logic supply voltages	5 V_{DC} & 3.3 V_{DC} 3.3 V should be powered up after 5 V within 0 ms to 10 ms range. Power up ramp time should be between 1 ms and 10 ms. The maximum allowed tolerances for logic supplies is ± 1.5%. The 5 V input can have a peak current consumption up to 0.35 A during 10 ms. EherCAT version requires an additional power supply (MAGNETICS_CT). This can be 3.3 V (for simplicity) or 1.8 V (to reduce power consumption by 100 mW).
Output reference voltages	3.3 V with 10 mA source / sink capability
Maximum continuous phase current	5 A ⓘ Typically, 5 A can be obtained working at 48 V, 40 kHz with an appropriate cooling to keep case temperature under 85 ºC. On higher temperatures an automatic current derating will be applied to protect the system. See Thermal and Power Specifications below. For disambiguation on current definitions please see Disambiguation on current values and naming for Ingenia Drives.

Maximum peak phase current	10 A @ 1 sec ⓘ Notice that peak current could be limited by an automatic current derating algorithm. In order to get 10 A, drive temperature should be kept below 60 ºC.
Maximum continuous output power	> TBD W ⓘ How the output power is calculated in an Ingenia drive.
Efficiency	Up to TBD %
Maximum DC Bus voltage utilization	95%
Standby logic supply consumption	~ 1 W typ. ⓘ See details and conditions in the section below.

4.2.2. Motion Control Specifications

Supported motor types	• Rotary brushless (SVPWM and Trapezoidal) • Rotary brushed (DC) • Voice Coils (single coil)
Power stage PWM frequency (configurable)	10 kHz, 25 kHz (default), 50 kHz
Current sensing	3 phase, shunt-based current sensing. 16 bit ADC resolution. Accuracy is ±2% full scale
Current sense resolution	0.457 mA/counts
Current sense range	± 15 Apk (full range)
Max. Current loop frequency	50 kHz
Max. servo loops frequency (position, velocity & commutation)	25 kHz @ 50 kHz current loop

Feedbacks	• Digital Halls
	• Quadrature / Incremental encoder
	• 2x Absolute Encoder:
	  • BiSS-C
	  • SSI
	All feedback inputs are single-ended, 3.3 V logic levels.
	
	Not all the existing absolute encoders are supported. Contact Ingenia for further information.

Supported target sources	Network communication (EtherCAT / CANopen)
Control modes	• Cyclic Synchronous Position • Cyclic Synchronous Velocity • Cyclic Synchronous Current • Profile Position (trapezoidal & s-curves) • Profile Velocity • Interpolated Position (P, PT, PVT) • Homing

4.2.3. Inputs/Outputs and Protections

General purpose Inputs and outputs	2x non-isolated single-ended digital inputs - 3.3 V logic level. (Option to have 4) Can be configured as: • General purpose • Positive or negative homing switch • Positive or negative limit switch • Quick stop input • Halt input 2x non-isolated single-ended digital outputs - 3.3 V logic level, 3 mA max. sink / source current. (Option to have 4) Can be configured as: • General purpose • Operation enabled event flag • External shunt braking resistor driving signal • Health flag 2x ±3.3 V ,16-bit, differential analog inputs for load cells or torque sensors. Can be read by the Master to close a torque loop. 1x 3.3 V, analog output.
Dedicate digital output	Dedicated 3.3 V digital output for Fault Signal status.

Shunt braking resistor output	Configurable over any of the digital outputs (see above). Enabling this function would require an external transistor or power driver.
Motor brake output	Dedicated, PWM-capable, 3.3 V digital output for driving a mechanical brake. Turn-on and turn-off times are configurable. Enabling this function would require an external transistor or power driver.
Safe Torque OFF inputs	2x dedicated, non-isolated STO digital inputs (3.3 V and 5 V tolerant).
Motor temperature input	1x dedicated, 3.3 V, 12-bit, single-ended analog input for measuring motor temperature. NTC, PTC, RTD, linear voltage sensors , silicon-based sensors and thermal switches are supported.

Protections	• Hardcoded / hardwired Drive protections:
	  • Automatic current derating on voltage, current and temperature
	  • Short-circuit Phase to DC bus
	  • Short-circuit Phase to Phase
	• Configurable protections:
	  • DC bus over-voltage
	  • DC bus under-voltage
	  • Drive over-temperature
	  • Drive under-temperature
	  • Motor over-temperature (requires external sensor)
	  • Current overload (I^2t). Configurable up to Drive limits
	  • Voltage mode over-current (with a closed current loop, protection effectiveness depends on the PID).
	• Motion Control protections:
	  • Halls sequence / combination error
	  • Limit switches
	  • Position following error
	  • Velocity / Position out of limits

4.2.4. Communication for Operation

EtherCAT **(DEN-NET-E)**	CANopen over EtherCAT (CoE) File over EtherCAT (FoE) Ethernet over EtherCAT (EoE)

CANopen / Ethernet **(DEN-NET-C)**	CiA-301, CiA-303, CiA-305, CiA-306 and CiA-402 (4.0) compliant. 125 kbps to 1 Mbps (default). Non-isolated. Termination resistor not included. Note: Ethernet port 1 can be used to configure the drive

4.2.5. Environmental Conditions

Environmental test methods	IEC 60068-2
Case temperature (Operating)	-20 °C to +85 °C Check the Current Derating section below.
Case temperature (Non-Operating)	-40 °C to +100 °C
Thermal Shock (Operating)	25 °C to 60 °C in 25 min
Maximum Humidity (Operating)	up to 95%, non-condensing at 60 °C
Maximum Humidity (Non-Operating)	up to 95%, non-condensing at 85 °C
Altitude (Operating)	-400 m to 2000 m
Vibration (Operating)	5 Hz to 500 Hz, 4/5 g
Mechanical Shock (Operating)	±15g Half-sine 11 msec
Mechanical Shock (Non-Operating)	±15g Half-sine 11 msec

4.2.6. Reliability Specifications

MTBF	> 450.000 h Based on FIDES method for Standard Life Profile at 40 °C average. Other scenarios available on demand.

4.2.7. Mechanical Specifications

Horizontal dimensions	33 mm x 17.6 mm
Height	6 mm
Weight	8 gr

4.2.8. Compliance

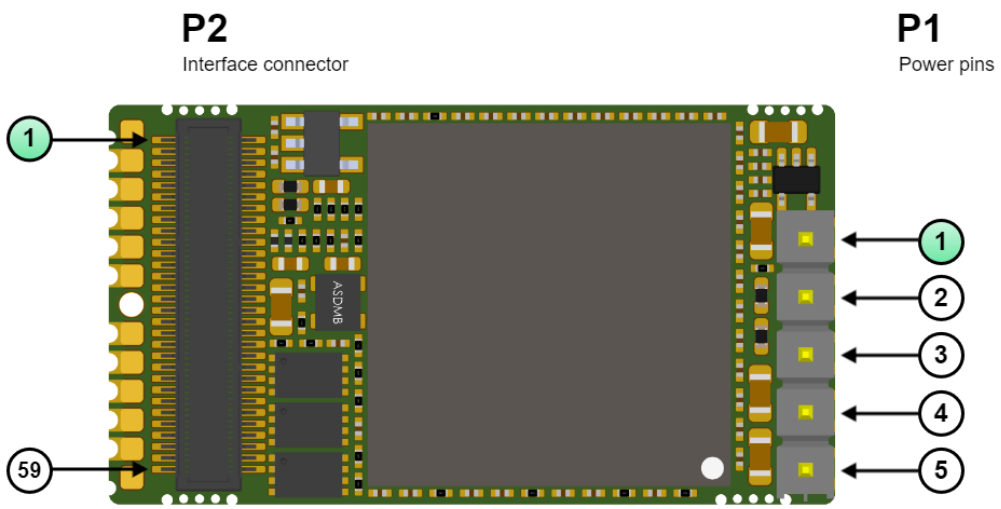
EC Directives	**CE Marking** • **LVD:** Low voltage directive (2014/35/EU) • **EMC:** Electromagnetic Compatibility Directive (2014/30/EU) • **Safety:** Machinery Directive (2006/42/EC) • **RoHS 3:** Restriction of Hazardous Substances Directive (2011/65/UE + 2015/863/EU)
Electromagnetic Compatibility (EMC) Standards	• IEC 61800-3:2017 • IEC 61000-6-2:2016
Product Safety Standards	• IEC/EN 61800-5-1: Adjustable speed electrical power drive systems - Safety requirements - Electrical, thermal and energy
Functional Safety Standards	**Safe Torque Off (STO)** - Certification pending • IEC 61800-5-2:2016 : **SIL3** • IEC 61508:2010 : **SIL3** • EN ISO 13849-1:2015 : **PLe** Cat. 3
Environmental Test methods	IEC 60068-2: • IEC 60068-2-1:2007: Test Ad, Cold • IEC 60068-2-2:2007: Test Be, Dry Heat • IEC 60068-2-38:2009: Test Z/AD, Composite temperature / humidity cyclic • IEC 60068-2-78:2012: Test Cab, Damp heat, steady state • IEC 60068-2-6:2007: Test Fc: Vibration (sinusoidal) • IEC 60068-2-27:2008: Test Ea: Shock

4.3. Product Revisions

Revision	Date	Notes
1	09-jun-2021	Initial version

5. Pinout

5.1. Connectors Overview



5.2. P1 Power pins

Gold plated 2.54 mm pitch pins.

#	Signal name	Type	Description	WARNING, POWER TERMINALS!
1	GND	Power	Power supply negative (Power Ground). Internally connected to GND_D.	 Power pins can have high voltages > 50 V, always respect clearance and creepage requirements (Typ > 0.25 mm)! Dimension PCB traces and connectors according to the current of the application!
2	+VBUS		Power supply positive (DC bus).	
3	PHASE_A		Motor phase A for 3-phase motors, positive for DC / Voice coil motors.	
4	PHASE_B		Motor phase B for 3-phase motors, negative for DC / Voice coil motors.	
5	PHASE_C		Motor phase C for 3-phase motors (do not connect for DC motors).	

Mating connector: TE connectivity 8134-HC-8P2, 5 A press-fit socket. This option allows plugging and unplugging the drive.

Soldering the power pins reduces conduction losses by minimizing contact resistance. It can also improve thermal performance by providing a preferential path for heat dissipation from the power stage to the environment. This is not mandatory but would reduce the temperature of the drive a few ºC during operation depending on the interface board layout.

5.3. P2 Interface connector

#	Signal name	Description	Type	#	Signal name	Description	Type
1	GND_D	Digital signal Ground.	Power	**2**	GND_D	Digital signal Ground.	Power
3	PHY1_TX_P	Port 1 Ethernet physical layer differential pairs. 50 Ω pull-up termination resistors are included on the drive. Magnetics with the center tap connected to MAGNETICS_CT (pin 54) must be added externally. If this port is not used leave these pins unconnected.	I/O	**4**	3.3V_REF	3.3 V voltage reference output with sink/source capability up to ±10 mA. Excessive current demand or noise coupled to this pin can cause a loss of performance or even malfunction: route by following the best layout practices.	Power output
5	PHY1_TX_N			**6**	AN1_OUT	0 to 3.3V Analog output 1	Analog output
7	PHY1_RX_P			**8**	AN1_P	Analog input 1. Can be used as a command source or for torque sensing.	16 bit differential analog input
9	PHY1_RX_N			**10**	AN1_N		
11	\ETH1_LED_LINK	Ethernet Port 1 Link signaling. Must be connected to a high impedance or be buffered to drive a (typically) green LED. Use an inverting buffer to drive the LED anode or an open collector element to sink the cathode current.	Output	**12**	AN2_P	Analog input 2. Can be used as a command source or for torque sensing.	16 bit differential analog input
13	\STO1	Safe Torque Off input 1 (non-isolated). Both \STO1 and \STO2 must be high-level (3.3 V and 5 V level compatible) to allow operation of the motor. Holding different logic states (STO1 ≠ STO2) for more than 1s will cause a latching fault.	Input	**14**	AN2_N		

15	GND_D	Digital signal Ground.	Power	**16**	MOTOR_TEMP	Motor temperature sensor dedicated analog input. 0 to 3.3 V level high impedance input. The connection of the sensor should be done between GND_D and MOTOR_TEMP with a pull-up resistor (recommended value 1.65 kΩ) to 3.3 V_REF	12 bit single-ended analog input
17	\STO2	Safe Torque Off input 2 (non-isolated). Both \STO1 and \STO2 must be high-level (3.3 V and 5 V level compatible) to allow operation of the motor. Holding different logic states (STO1 ≠ STO2) for more than 1s will cause a latching fault.	Input	**18**	GPI1	Digital Input 1.	Input
19	CAN_TX	3.3 V TTL-levels Transmit pin of CAN data frame. Requires an external transceiver to shift into CAN physical layer.	Output	**20**	GPI2	Digital Input 2.	Input
21	CAN_RX	3.3 V TTL-levels Receive pin of CAN data frame. Requires an external transceiver to shift into CAN physical layer. If not used leave unconnected or pull-up high.	Input	**22**	GPI3	Digital Input 3.	Input
23	DNC	Reserved. Do not connect (leave floating).	-	**24**	GPI4	Digital Input 4.	Input
25	DNC	Reserved. Do not connect (leave floating).	-	**26**	GPO1	Digital Output 1.	Output
27	DNC	Reserved. Do not connect (leave floating).	-	**28**	GPO2	Digital Output 2.	Output
29	DNC	Reserved. Do not connect (leave floating).	-	**30**	PWM_BRAKE	PWM output for driving a mechanical brake. Configurable up to 40 kHz. A high level indicates the motor is free to move.	Output
31	GND_D	Ground	Power	**32**	ABSENC1_DATA	Data input for Absolute Encoder 1 (supports SSI or up to 2 BiSS-C encoders connected in daisy chain topology).	Input

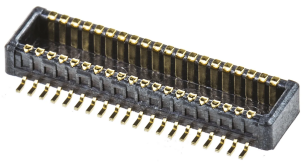
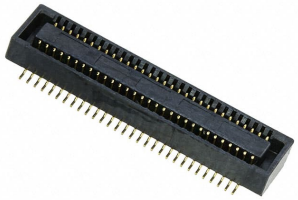
33	DNC	Reserved. Do not connect (leave floating).	-	**34**	ABSENC1_CLK	Clock output for Absolute Encoder 1.	Output
35	BOOT/DNC	This pin can be pulled down to GND_D to force enter boot mode during power-up. Typically not necessary. If not used, always leave unconnected or pulled up with a 10 kΩ resistor. Never leave this pin permanently pulled down, as this would block the Denali boot mode.	I/O	**36**	GND_D	Digital signal Ground.	Power
37	DNC	Reserved. Do not connect (leave floating).	-	**38**	ABSENC2_CLK	Clock output for Absolute Encoder 2.	Output
39	DNC	Reserved. Do not connect (leave floating).	-	**40**	ABSENC2_DATA	Data input for Absolute Encoder 2 (supports SSI or BiSS-C encoders).	Input
41	STO_STATUS	STO report output. Used for monitoring purposes. It is hardware-based logic AND between STO1 and STO2 lines. When it is in low level, the motor will not be enabled and STO will be active. When it is in high level the motor phases can be enabled.	Output	**42**	DIG_ENC_1A	Incremental encoder 1 A.	Input, 3.3 V level single-ended.
43	FAULT_SIGNAL	Fault state signaling output. Can directly drive a (typically) red LED anode at 3.3 V up to 3 mA.	Output	**44**	DIG_ENC_1B	Incremental encoder 1 B.	
45	ECAT_CAN_RUN	State-machine RUN green LED output for EtherCAT and CANopen. Can directly drive a green LED anode at 3.3 V up to 3 mA.	Output	**46**	DIG_ENC_1Z	Incremental encoder 1 Index.	
47	ECAT_CAN_ERR	State machine ERROR red LED for EtherCAT and CANopen. Can directly drive a red LED anode at 3.3 V up to 3 mA.	Output	**48**	HALL_1	Digital hall 1.	Input, 3.3 V level single-ended

49	\ETH0_LED_LINK	Ethernet Port 0 Link signaling. Must be connected to a high impedance or be buffered to drive a (typically) green LED. Use an inverting buffer to drive the LED anode or an open collector element to sink the cathode current.	Output	**50**	HALL_2	Digital hall 2.	
51	PHY0_TX_P	Port 0 Ethernet physical layer differential pairs. 50 Ω pull-up termination resistors are included on the drive. Magnetics with the center tap connected to MAGNETICS_CT (pin 54) must be added externally. If this port is not used leave these pins unconnected.	I/O	**52**	HALL_3	Digital hall 3.	
53	PHY0_TX_N			**54**	MAGNETICS_CT	Dedicated voltage output for the EtherCAT magnetics center tap and PHYs. This power supply can be powered at either: • 3.3 V, for lowest component, connect to pin 56 to an external 3.3V power supply. • 1.8 V for low power option. This reduces the total power supply consumption by approximately 100 mW.	Power input
55	PHY0_RX_P			**56**	3V3_D	3.3V power supply input. A well-regulated ±1.5%, low ripple, 1 A peak, 250 mA continuous source must be used. 3.3 V power supply should have a rise time between 0.5 ms and 10 ms, and the delay from 5 V supply should be between 0 ms and 10 ms.	Power input
57	PHY0_RX_N			**58**	5V_D	5 V logic power supply input. A well regulated ±1.5%, low ripple, 500 mA A peak, 250 mA continuous source must be used.	Power input
59	GND_D	Digital signal Ground.	Power	**60**	GND_D	Digital signal Ground.	Power

Notes and naming conventions:

- All pins are tolerant to 3.3 V unless otherwise noted.
- Unused digital outputs should be left unconnected.
- Unused digital inputs should be connected to GND_D.
- Unused analog inputs should be connected to 1.65V_REF.
- "_P" and "_N" indicates positive and negative terminals of differential signals
- "\" Indicates inverted (active low) signal

- "NC" means Not Connected. Pins marked with NC can be tied to GND or 3.3 V, but the best practice is to leave them unconnected.
- "DNC" means Do Not Connect. Pins marked with DNC must not be tied to any driving voltage, including GND or 3.3 V.
- "CLL" means Connect to Low Level. Pins marked with CLL must be tied or pulled down to 0 V.
- "CHL" means Connect to High Level. Pins marked with CHL must be tied or pulled up to 3.3 V.

Manufacturer	Denali NET connector	Required mating connector	Description
Molex			60-pin stacking board connector. 0.5 mm pitch. Center strip, gold-plated surface mount contacts. 2.5 mm stacking height. Molex SlimStack connectors operation and storage temperature, when mounted, is -45 °C to 105 °C.
	MOLEX 53885-0608	MOLEX 54102-0604	

6. Safe Torque Off (STO)

The Safe Torque Off (STO) is a functional safety system that prevents motor torque in an emergency event while Denali NET remains connected to the power supply. When STO is activated, the power stage is disabled by hardware and the drive power transistors are disconnected, no matter what control or firmware does. The motor shaft will slow down until it stops under inertia and frictional forces. Although not common, in the event of a failure of the power stage during an STO situation, the maximum expected motor movement with torque can be up to 180º electrical degrees. The system must be designed to avoid any hazard in this situation.

If the STO inputs are not energized, the transistors of the power stage are turned off and an STO fault is notified. In order to activate the power stage, and therefore allow the motor operation, the two STO inputs must be energized (high level, typically 5V). STO inputs 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.

In order to ensure redundancy and safety, the Denali NET includes 2 separate STO inputs that must be activated or deactivated simultaneously (maximum 1.4 s mismatch). A difference of state between \STO1 and \STO2 inputs will be interpreted as an abnormal situation after 1.4 s the drive will be latched in a fault state. **A power supply reset is necessary to remove this STO abnormal error.**

Since Denali NET is a pluggable module intended for being integrated on an electronic interface board, **it requires some external electronic components to fulfill the safety requirements:**

- External **overvoltage protection (or equivalent) is required to limit STO input voltage.**
- **Input current limiter** to avoid system destruction in case of internal fault. The current limit can be implemented with a resistor in series.
- **Input low-state must be guaranteed by means of a pull-down resistor** or equivalent (active output). Otherwise, safety function fault tolerance and reaction times, won't be fulfilled.

6.1. Safety Function Specifications

Safety Function Specification	**Value**	
Standards compliance	**Targeted standards (certification pending):** • EN 61800-5-2:2017 • EN 61508:2010 • EN ISO 13849-1:2015	
Safety function	Safe Torque Off (STO)	
Safety relevant parameters according to IEC 61508:2010 ***(certification pending)***	Safety integrity level	SIL3
	PFH	*TBC (< 10^{-7} 1/h)*
	SFF	> 99 % (High)

Safety Function Specification	Value	
Safety relevant parameters according to EN ISO 13849-1:2015 ***(certification pending)***	PL	e
	Category	3
	DC	99% High
	MTTFd	≥ 100 years (High)
Safety Function Reaction Time	t < 5.1 ms The Safety Function Reaction time is measured as the time since one of the STO inputs (STO1 or STO2) goes below 0.8 V and the STO function actuates (power transistors deactivated).	
Fault Reaction Time	t < 8 ms The worst-case fault reaction time is on the event of an Abnormal STO.	
High-demand mode	The EUC (Equipment Under Control) is considered as a high-demand or continuous demand mode system.	
Mission Time	The mission time of the EUC is of 20 years.	
Diagnostic Time Interval	In order to guarantee the correct operation of the safety functions, the user has to check the STO function regularly, performing an STO External Diagnostic Test (see further information below). The diagnostic test interval is defined as a minimum of 1 activation per 3 months.	

6.2. Integration Requirements

Integration Requirement	Value	
STO Interface electrical characteristics	Input pins	\STO1 and \STO2
	Number of independent channels	2
	Type of Inputs	Digital inputs with ESD protection. Maximum nominal Voltage 7V. Maximum voltage in case of an external overvoltage fault 12 V.

	Mandatory External Requirements	▪ Input current limit (in case of internal short-circuit) = 50 mA ▪ Resistive pull-down of maximum 7.5 kΩ or equivalent (active output with 660 µA min current sink capability). ▪ Overvoltage protection on \STO signals, limiting to 12 V in case of external fault.
	Maximum input LOW level (VIL)	0.8 V (below this value the STO is ACTIVE, no torque can be applied to the motor)
	Minimum Input HIGH level (VIH)	2.8 V (above this value the STO input is inactive, torque can be applied to the motor)
	Maximum absolute ratings	7 V max nominal voltage; 12 V maximum failure voltage
	Input current (externally limited)	50 mA
	ESD capability	IEC 61000-4-2 (ESD) ± 15 kV (air), ± 8 kV (contact)
STO Interface timing characteristics	STO activation time (Safety function Reaction Time)	t < 5.1 ms
	STO deactivation time	t < 2 ms
	Minimum, non-detected STO short pulse	t < 400 µs The Safety controller can transmit short pulses to STOx inputs for diagnostics purposes. These pulses will be ignored by the safety circuit and will not stop the power stage but can be read from firmware for system diagnostics, see: Drive protections Register 0x51A.
	Abnormal STO diagnostic time	≤ 5.2 ms (Activation STO)
	Abnormal STO latching time	1.4 s ~ 3.4 s (Latching state, permanent activation of STO until power reset)
	Power supply diagnostic time	3.3 V over-voltage 200 ns
Logic Supply Voltage Range	5 V ± 3% (range from 4.85 V to 5.15 V; maximum failure voltage 24 V). During the overvoltage fault system becomes unoperational, but safety function is maintained.	
Power Supply Voltage Range [1]	48 V SELV (range from 8 V to 60 V; maximum failure voltage 60 V)	
Motor Type	STO safety function is only considered when the drive is controlling **three-phase permanent magnet synchronous rotating motors.** STO does not apply to DC brush motors.	

<table>
<tr><td>Uncontrolled Motor Movement</td><td colspan="2">Uncontrolled Motor Movement
In the event of a failure in the power stage, the motor shaft may rotate up to 180º electrical degrees. It is responsibility of the customer to prevent any hazards related ot this unexpected motor movement.</td></tr>
<tr><td rowspan="3">Environmental Conditions for STO</td><td>Pollution degree</td><td>Pollution degree 2 with an IP54 enclosure installation.</td></tr>
<tr><td>Over-
voltage category</td><td>II</td></tr>
<tr><td>Altitude</td><td>< 2000 m above sea level.</td></tr>
<tr><td rowspan="2">Temperature range for STO [2]</td><td>Operating Temperature</td><td>-20 ºC to 85 ºC</td></tr>
<tr><td>Storage Temperature</td><td>-40 ºC to 100 ºC</td></tr>
<tr><td>Diagnostics</td><td colspan="2">Internal power supply voltage monitors.

Differences between STO1 and STO2 cause abnormal fault. After 1.4 s a hardware latching condition disables the drive until power cycling.

Status of STO1, STO2, STO_REPORT, ABNORMAL_FAULT, and SUPPLY_FAULT can be read from the communications.

STO firmware notification
A STO stop is notified to the motion controller and creates a fault that can be read externally from any communication interface, however, STO operation is totally independent and decoupled from control or firmware.</td></tr>
<tr><td>EMC</td><td colspan="2">The interface board must meet the following EMC standards:

• IEC 61800-3:2017
• IEC 61000-6-2:2016
To fulfill the EMC requirements the use of the following elements is required:

Input EMI filter. Recommended: Cosel NBC-10-472 or equivalent.
Motor phases ferrite cable core. Recommended : 28B0773-050 or equivalent.
Properly grounded aluminum enclosure. See grounding recommendations for further information.</td></tr>
</table>

Environmental	The interface board must meet the following environmental standards: • IEC 60068-2-1:2007 • IEC 60068-2-2:2007 • IEC 60068-2-38:2009 • IEC 60068-2-78:2012 • IEC 60068-2-6:2007 • IEC 60068-2-27:2008

1: Although the drive can operate in a wider range of voltages as can be seen in Product Description, the system cannot be considered safe outside this range.

2: The drive can operate outside this temperature range as indicated in the Product Description, however, the system cannot be considered safe as the system reliability and safety margins would not meet the standards.

6.3. STO External Diagnostic Test

The operation of the STO diagnostic circuits must be verified at least once per 3 months. The following procedure details a method to verify the correct operation of the STO diagnostic circuits. Note that it is responsibility of the customer to prevent any hazards related to motor movement during this proof test.

The procedure requires the Denali NET to be connected to a brushless motor.

Procedure Step	Action
1	Power on the Denali NET with STO1 = low, STO2 = low.
2	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).
3	Verify that the power stage is not enabled by software (a fault should appear) or by hardware (checking the Motor phases voltage with a multimeter).
4	Provide STO1 = high, STO2 = low. Remain in this state more than 3.4 seconds.
5	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).
6	Verify that the power stage is not enabled by software (a fault should appear) or by hardware (checking the Motor phases voltage with a multimeter).
7	Provide STO1 = high, STO2 = high.
9	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).
10	Verify that the power stage is not enabled by software (a fault should appear) or by hardware (checking the Motor phases voltage with a multimeter).
11	Shut-down Denali NET supply and remain in this state for more than 10 seconds.
12	Power on the Denali NET with STO1= low, STO2 = high. Remain in this state more than 3.4 seconds.

Procedure Step	Action
13	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).
14	Verify that the power stage is not enabled by software (a fault should appear) or by hardware (checking the Motor phases voltage with a multimeter).
15	Provide STO1 = high, STO2 = high.
17	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).
18	Verify that the power stage is not enabled by software (a fault should appear) or by hardware (checking the Motor phases voltage with a multimeter).
19	Shut-down Denali NET supply and remain in this state for more than 10 seconds.
20	Power on the Denali NET with STO1= high, STO2 = high.
21	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).
22	Verify that the power stage can be enabled, allowing motor rotation. Do it by software (system should enter in motor enable state) or by hardware (checking the Motor phases voltage with a multimeter).

6.4. STO Operation States

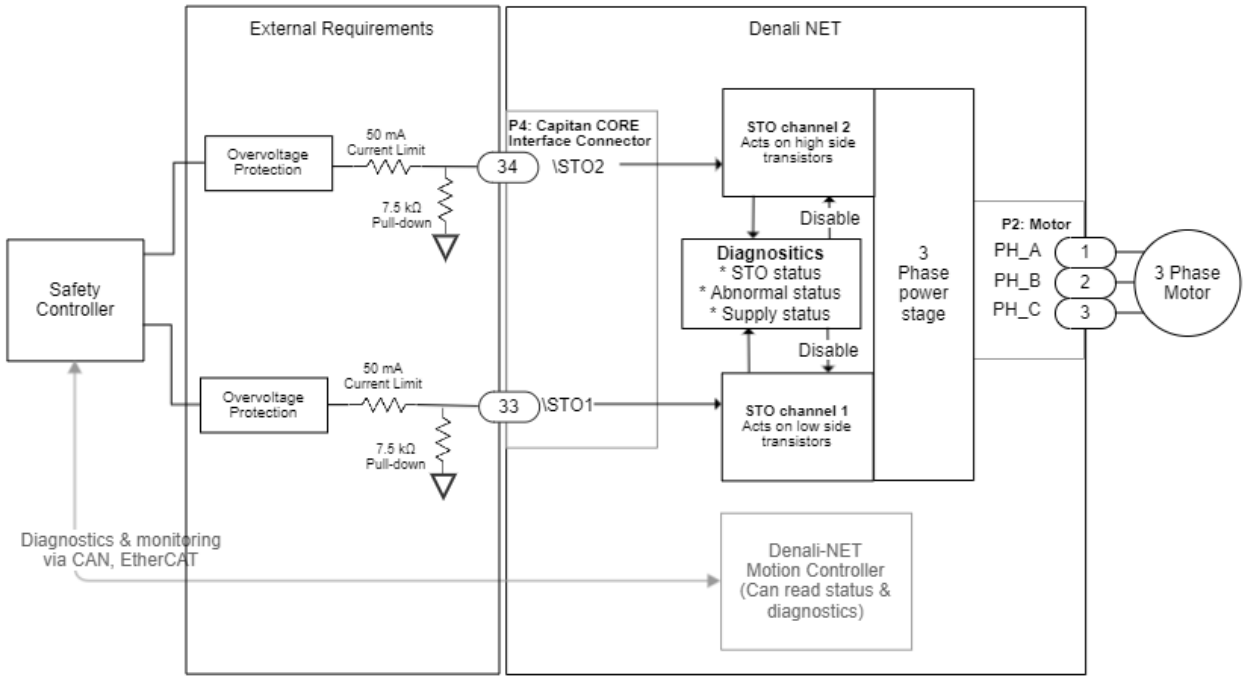
The truth table of the STO inputs is shown next indicating the different states of the system:

Mode	State	STO1 status / level		STO2 status / level		Power stage status	STO report bit status	STO abnormal fault	State description
Normal operation	**STO Enabled** (No torque to the motor)	0	< 0.8 V	0	< 0.8 V	OFF	0	0	The system logic is powered, but the STO function is activated. Therefore, no torque can be applied to the motor. STO trip is reported to the MCU and to the safety circuitry. This is intended safe torque off with dual-channel operation.

Mode	State	STO1 status / level		STO2 status / level		Power stage status	STO report bit status	STO abnormal fault	State description
	Torque enabled (STO inactive)	1	> 2.8 V	1	> 2.8 V	Can be enabled	1	0	The STO function is deactivated, and torque can be provided to the motor. The motor can run under firmware control. This is the normal operation state.
Abnormal operation	**Abnormal STO**	0	< 0.8 V	1	> 2.8 V	OFF	0	1	If any issue is detected on the dual-channel STO function (their state is different for a long period of time), an abnormal fault is active can be reported. This state avoids the application of torque to the motor. If this persists for > 1.4 s ~ 3.4 s the STO will lock in FAULT state. To reset this fault a power cycle is needed.
		1	> 2.8 V	0	< 0.8 V	OFF	0	1	
	Abnormal STO Latched	x	-	x	-	OFF	NOR (STO1, STO2)	1	After >1.4 s ~ 3.4 s of abnormal STO active, the driver will stay in this state until the power supply cycle.
	Abnormal Supply	x	x	x	x	OFF	x	x	If a voltage out of the limits is detected on the internal logic voltages, the system is conducted to a safe state, similar to power-off. Only if the safe logic voltages are recovered (usually after reparation or restart), the system can return to any other state.

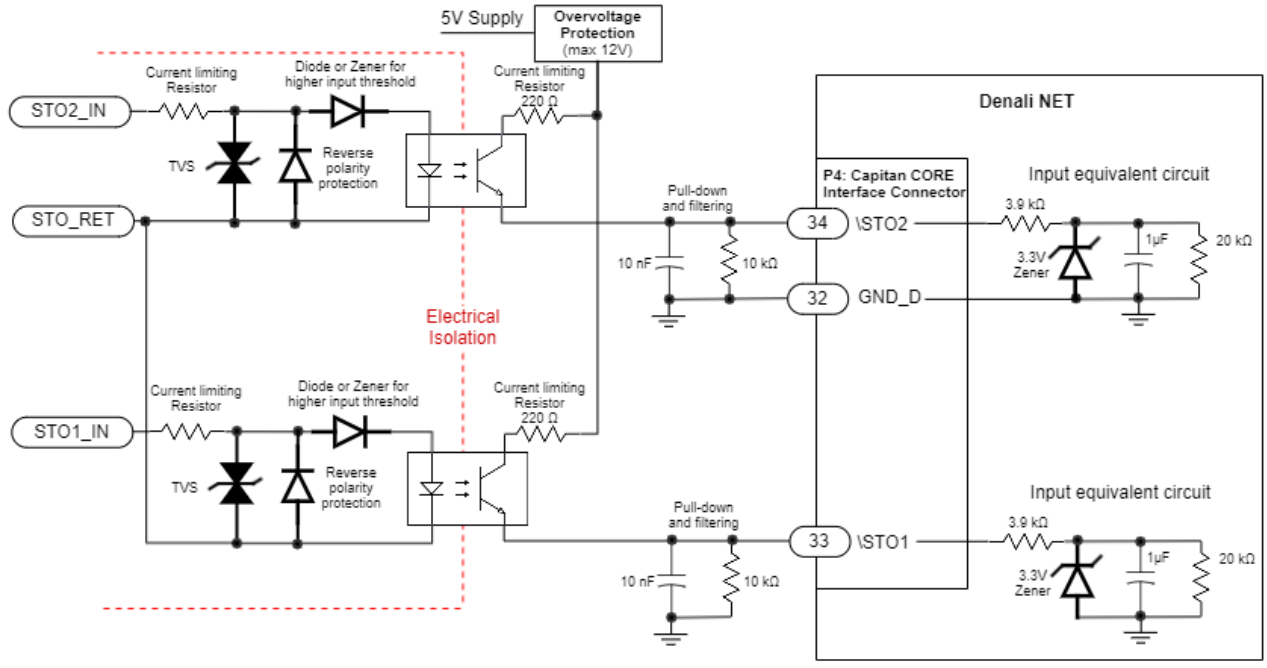
6.5. STO Inputs External Requirements

The following diagram summarizes the external requirements for the STO inputs.



6.6. Typical Interface Circuit

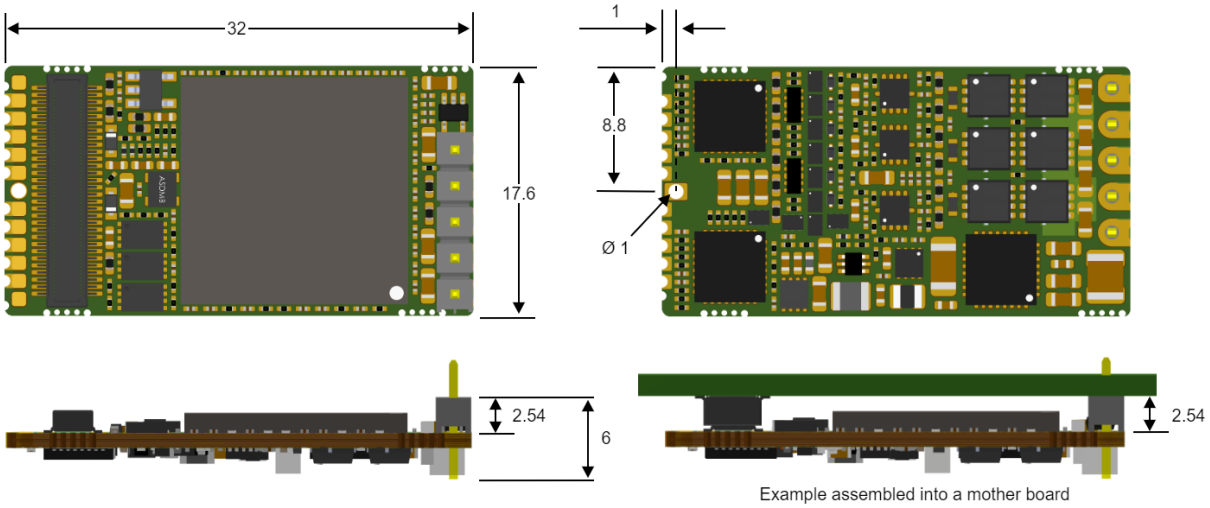
The following diagram shows a suggested circuit interface for the STO inputs.



STO1 and STO2 signals should always change at the same time with a maximum of 1.4 s mismatch. This is necessary to have 2 channel redundancy and allow diagnostics, as a mismatch will cause an abnormal fault.

7. Dimensions

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



3D Model

For further detail, download the STEP model or the PDF3D.