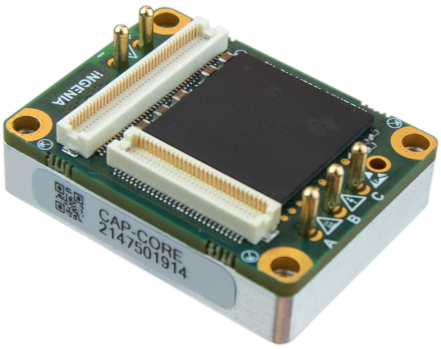
Capitan CORE - Product Manual



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

INGENIA-CAT S.L.

AVILA 124

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INGENIA passion for motion

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2. General Information

2.1. Manual revision history

Revision	Release Date	Changes	PDF
v1	13.11.2020	Initial version	

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

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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 ºC 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

Capitan CORE is a high 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**.

Capitan CORE can be interfaced by means of its proprietary SPI-based **Motion Control Bus** protocol.

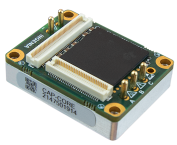
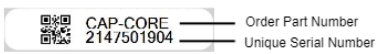
Main features:

- Ultra-small footprint
- 48 V_{DC}, 10 A continuous
- Up to 99% efficiency
- Up to 50 kHz current loop, 25 kHz servo loops
- 20 kHz ~ 200 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
- Low power AGVs
- UAVs
- Industrial highly integrated servomotors
- Smart motors
- Battery-powered and e-Mobility
- Low inductance motors
- Lab equipment

4.1. Part numbering

Product	Ordering part number	Status	Image	Label
Capitan CORE Pluggable servo drive with communication through proprietary **M**otion **C**ontrol **B**us protocol.	CAP-CORE	PRODUCTION		

For applications requiring a pluggable drive enabled with EtherCAT or CANopen, please see Capitan NET.

For applications requiring a ready-to-go product, also enabled enabled with EtherCAT or CANopen, please see Capitan XCR.

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	12 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	17 µF Note that CAP-CORE uses ceramic capacitors. The capacitance value varies with DC bias and temperature.
Logic supply voltage	4.9 V_{DC} ~ 5.1 V_{DC} A minimum of 500 mA should be provided. Higher current may be needed depending on the feedbacks used. Rise time of the 5 V supply must be < 5 ms
Maximum continuous phase current	10 A Typically, 10 A can be obtained working at 48 V, 50 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	20 A @ 1 sec Notice that peak current could be limited by an automatic current derating algorithm. In order to get 20 A, case temperature should be kept below 60 ºC.
Maximum continuous switch-off rectified current	• Without heatsink: 1 A @ 25 ºC • With heatsink: 1 A @ 85 ºC Notice that maximum current is dependent on temperature and heatsink attached. At higher temperature, the lower the current. For more information about heatsink applied, see Thermal and Power Specifications below. A continuous use of disabled power stage as rectifier is not recommended for thermal limitations.
Maximum continuous output power	> 500 W How the output power is calculated in an Ingenia drive.
Efficiency	Up to 99%

Maximum DC Bus voltage utilization	99.5% @ 20 kHz 98.9% @ 50 kHz 97.95% @ 100 kHz 96% @ 200 kHz Note 1: these values assume a Sinusoidal commutation and no load connected.
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)
Power stage PWM frequency (configurable)	20 kHz, 50 kHz (default) & 100 kHz 200 kHz option available upon request
Current sensing	3 phase, shunt-based current sensing. 16 bit ADC resolution. Accuracy is ±2% full scale
Current sense resolution	1.007 mA/counts
Current sense range	± 33 A
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
	• Absolute Encoder: up to 2 at the same time, combining any of the following:
	    • BiSS-C (up to 2 in daisy chain topology)
	    • 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 (Motion Control Bus) • Analog inputs 1 & 2 *MCBus is a SPI-based proprietary protocol for Ingenia CORE drives.

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	4x non-isolated single-ended digital inputs - 3.3 V logic level. Can be configured as: • General purpose • Positive or negative homing switch • Positive or negative limit switch • Quick stop input • Halt input 4x non-isolated single-ended digital outputs - 3.3 V logic level, 3 mA max. sink / source current. 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.
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, 5 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

MCB	Proprietary Motion Control Bus protocol based on SPI.

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	> 650.000 h Based on FIDES method for Standard Life Profile at 40 °C average. Other scenarios available on demand.
Isolation between aluminum case (PE) and live circuits	Basic insulation according to IEC 61800-5-1. > 200 MΩ. Measured between PE (case) and GND_P and +SUP and phases. Note: The drive includes 2 nF EMC capacitance between the power supply negative (GND_P) and the enclosure (PE).

4.2.7. Mechanical Specifications

Aluminium case	Yes (connectors side open). Minimum wall thickness > 0.75 mm.
Horizontal dimensions	34.5 mm x 26 mm
Height	10.30 mm (including Mezzanine connector) 14.59 mm (including full length of the power pins)
Weight	17.5 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	13.11.2020	Initial version

4.4. Thermal and Power Specifications

4.4.1. Standby power consumption

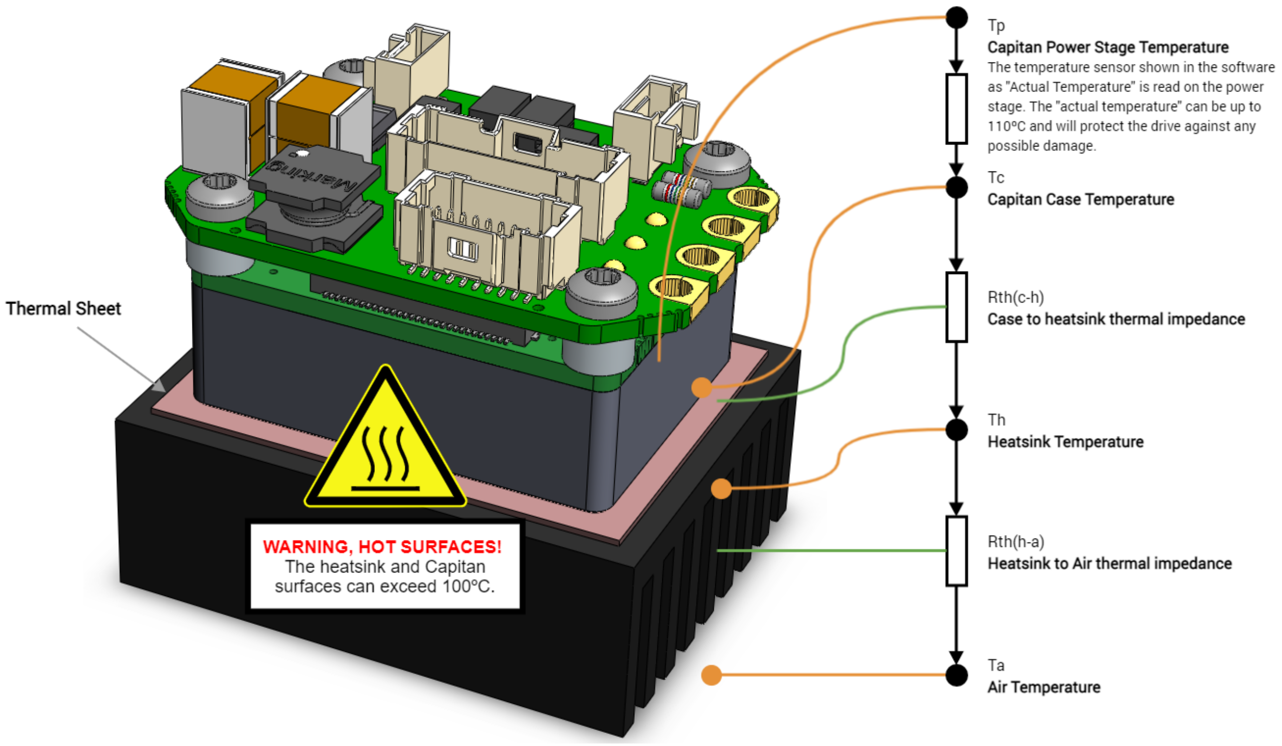
The following table shows the standby power consumption when the Capitan power stage is disabled, no feedbacks or I/Os are connected. At this point the power consumption comes from the 5 V supply input only. The table also shows the "active standby" dc bus power consumption when the power stage is enabled, motor current is set to 0 and housing temperature is kept at 50 ºC.

Power supply voltage	Standby 5 V logic supply consumption	Power consumption switching at 0 current			
		20 kHz	50 kHz	100 kHz	200 kHz
12 V	1.03 W (logic supply consumption does not depend on bus voltage)	0.02 W	0.04 W	0.07 W	0.14 W
24 V		0.05 W	0.12 W	0.22 W	0.44 W
48 V		0.16 W	0.37 W	0.68 W	1.31 W
60 V		0.23 W	0.52 W	0.98 W	1.91 W

4.4.2. Thermal model

The Capitan Core is designed to be mounted on a cooling plate or heatsink to achieve its maximum ratings. In order to calculate the heatsink requirements, the power dissipation can be estimated below.

In some low power applications, the Capitan is NOT required to be mounted to any heatsink. In this case its thermal resistance from housing/case to ambient $\mathbf{R_{th(h-a)}}$ can be estimated between 8 K/W, to 12 K/W assuming 10 cm clearance to allow air convection at sea level. A good thermal design of the PCB providing big thermal ground planes on the contact areas can greatly increase the heat dissipation and reduce $R_{th(h-a)}$ significantly.



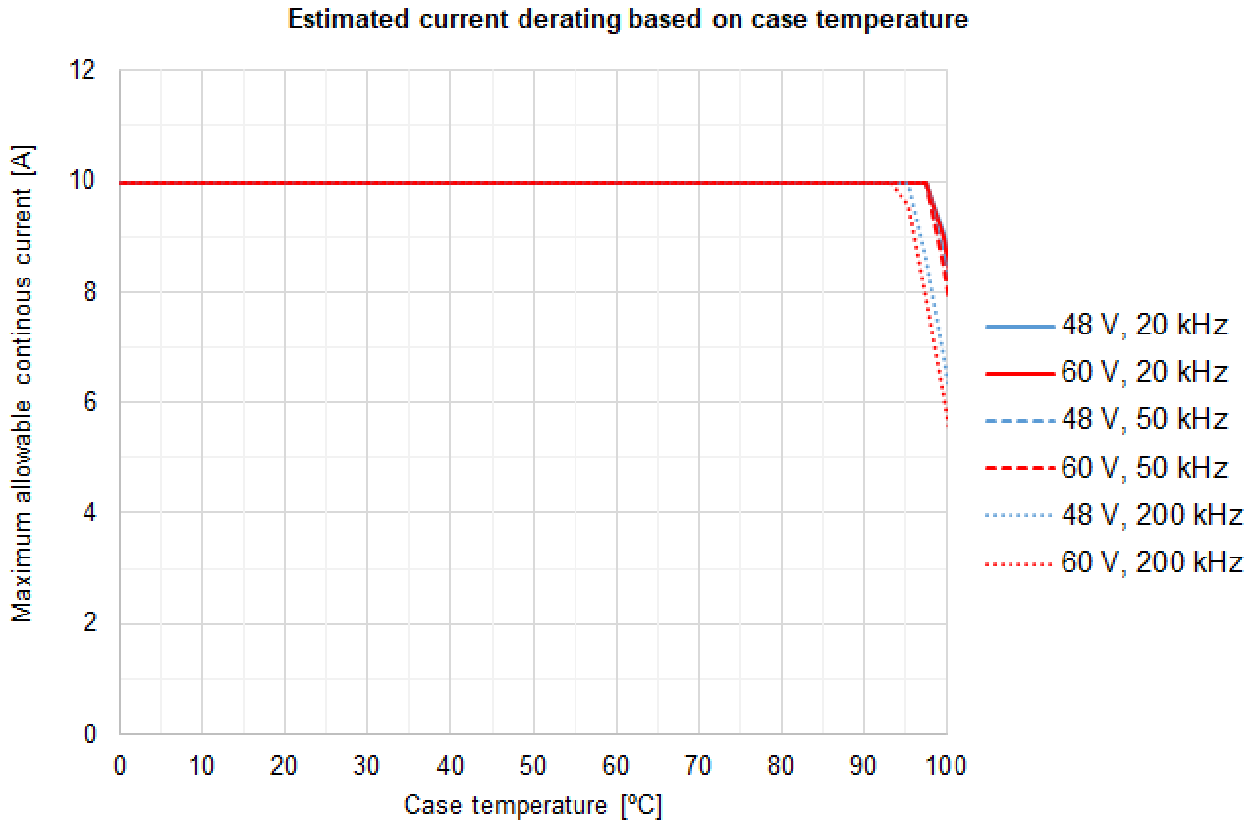
*Product shown differ from Capitan CORE.

4.4.3. Current derating

The following figure show the maximum motor phase current at different case temperatures and operating points. The graph expresses the achievable current including the derating algorithm that limits the current based operation conditions and the power stage temperature.

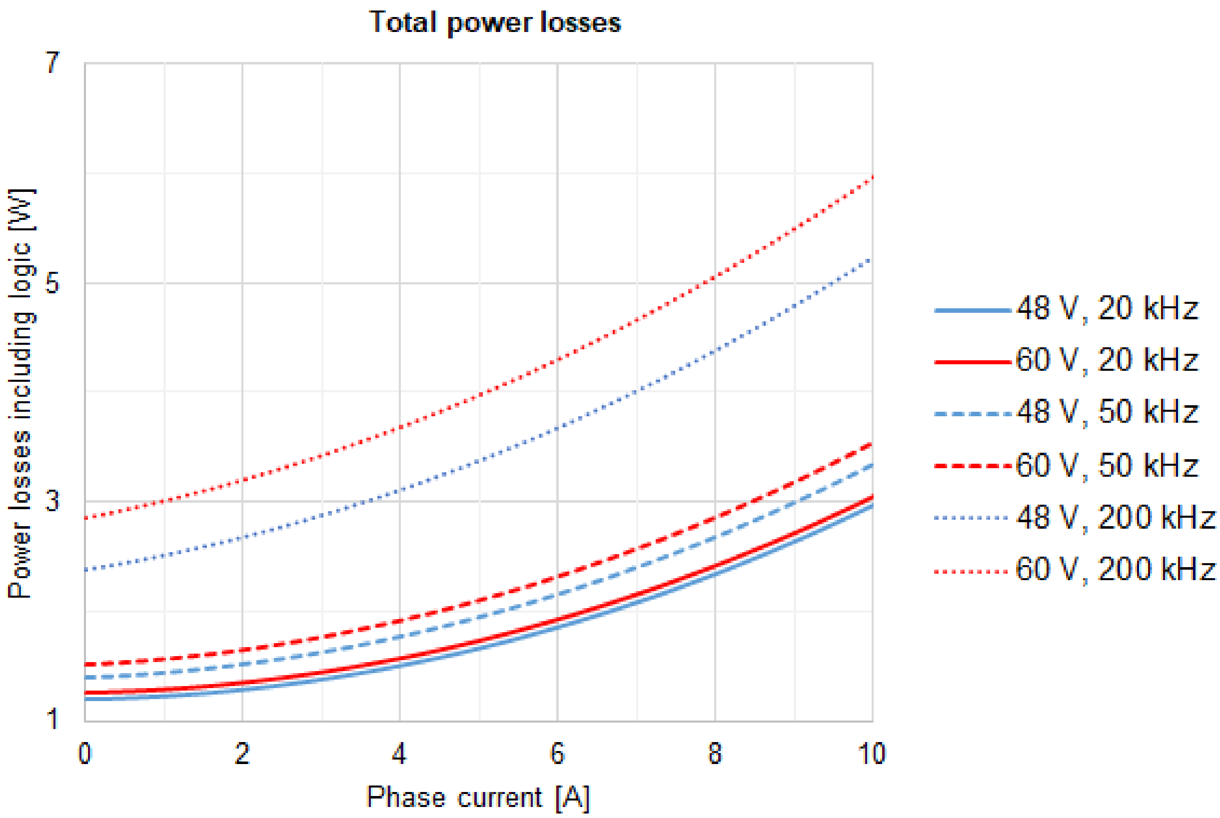
Notice that current is expressed in crest value for a 3 phase BLAC motor. For further clarifications and conversion to equivalent RMS values please refer to Disambiguation on current values and naming for Ingenia Drives.

To ensure a proper performance of Capitan XCR, the **case temperature should be held always below 85 ºC ($T_{c\text{-}max}$ = 85 ºC).**



4.4.4. Heat dissipation and heatsink calculation

Following figure show the total power losses at different operating points. This includes logic supply which is an important contributor at low loads. As can be seen, lower PWM frequency and voltage leads to lower power losses.



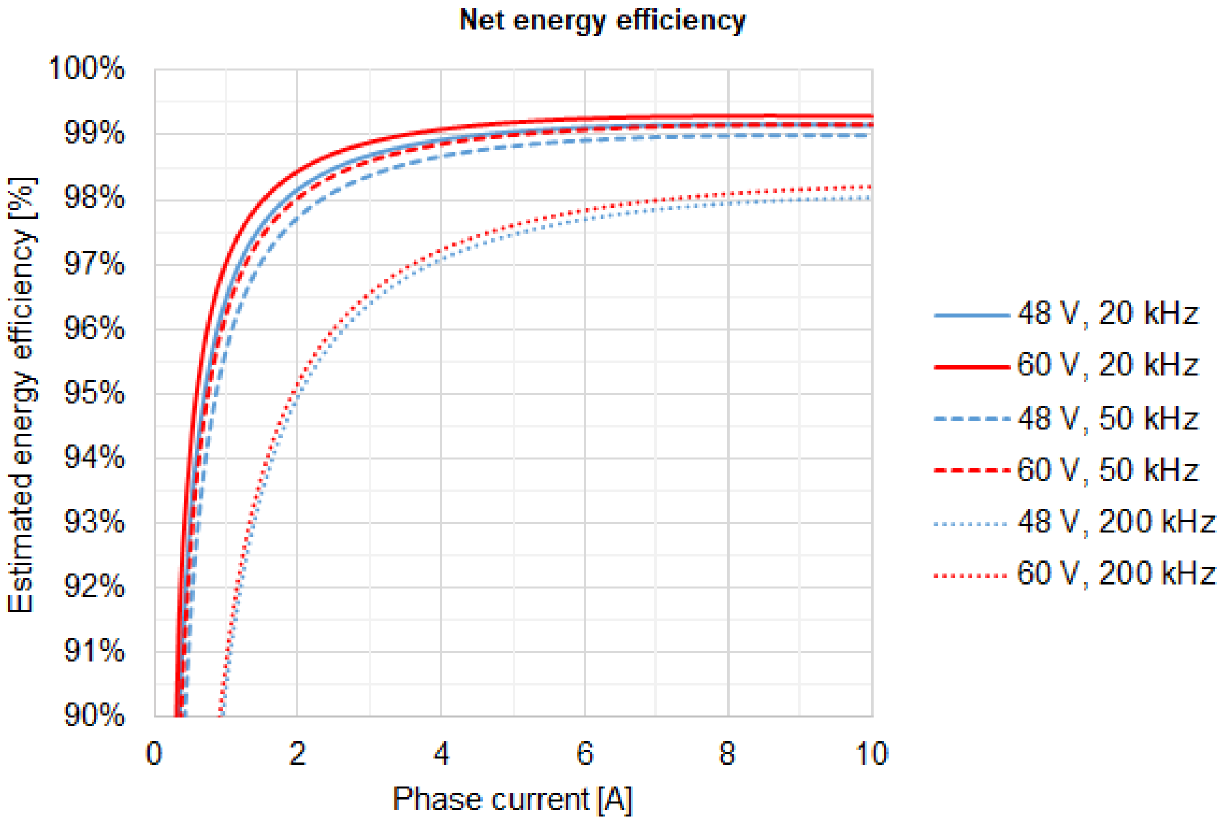
1. Please, use the following procedure to determine the required heatsink:
   a. Based on the voltage & continuous (averaged) current required by your application and Current derating graph determine the Case temperature $\mathbf{T_c}$. Remember that Case temperature must be always below 85 °C (T_c < 85 °C)
      i. For example: If the application requires 10 A @ 60 V (20 kHz) the T_c will be 85 °C
   b. Based on the voltage & continuous current required by your application and Power losses graph determine the generated Power Losses $\mathbf{P_L}$ to be dissipated.
      i. For example: If the application requires 10 A @ 60 V (20 kHz) the P_L will be 3.06 W
   c. Determine the Thermal impedance of the used thermal sheet $\mathbf{R_{th(c\text{-}h)}}$
      i. For example, a thermal sheet TGX-150-150-0.5-0, which has an estimated thermal impedance of $R_{th(c\text{-}h)}$ = 0.2 K/W
   d. Based on the ambient temperature and using the following formula determine the maximum thermal impedance to air of the required heatsink $\mathbf{R_{th(h\text{-}a)}}$

$$R_{th(h-a)} \leq \frac{T_c + P_L \cdot R_{th(c-h)} - T_a}{P_L}$$

   a. For example: If the application requires 10 A @ 60 V (20 kHz) working at T_a = 25 °C and we use a thermal sheet with $R_{th(c\text{-}h)}$ = 0.2 K/W the required thermal impedance of the heatsink will be $R_{th(h\text{-}a)}$ = 12.8 K/W

4.4.5. Energy efficiency

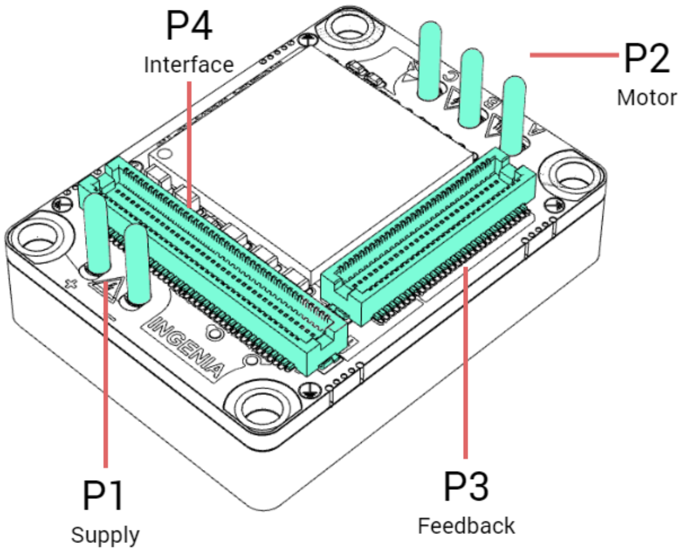
The following graph shows the **net energy efficiency including logic** for various operation points assuming 50°C case temperature and maximum output power. Very high efficiencies > 99% can be achieved at 20 kHz PWM frequency.



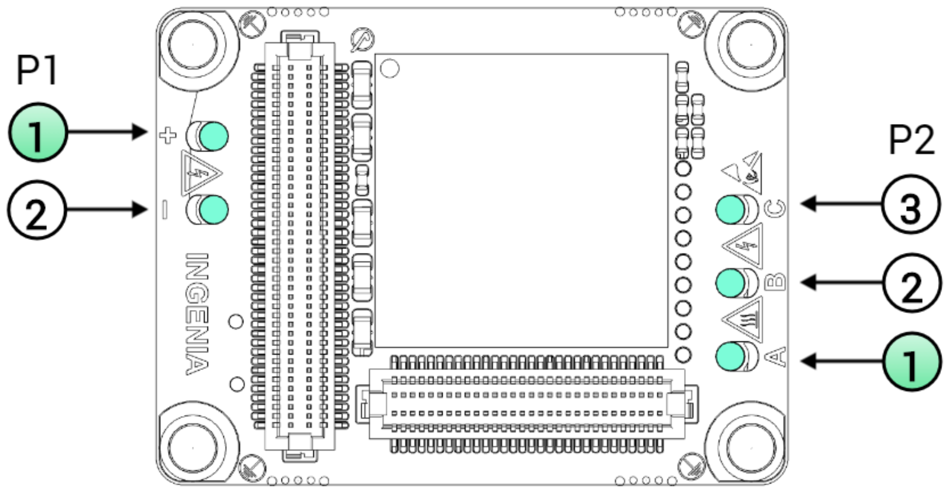
Net energy efficiency
Estimated energy efficiency [%]
100%
99%
98%
97%
96%
95%
94%
93%
92%
91%
90%
0
2
4
6
8
10
Phase current [A]
48 V, 20 kHz
60 V, 20 kHz
48 V, 50 kHz
60 V, 50 kHz
48 V, 200 kHz
60 V, 200 kHz

5. Pinout

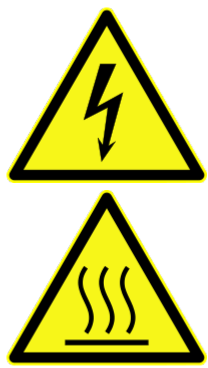
5.1. Connectors Overview



5.2. P1 and P2 Power pins



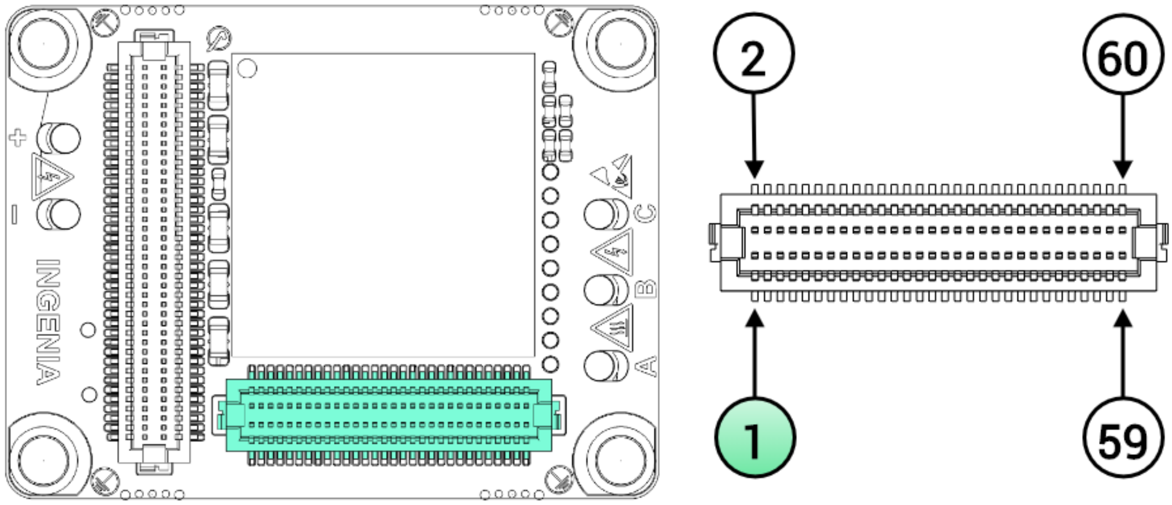
P1 Supply Power pins				
Pin	**Name**	**Type**	**Function**	**WARNING, POWER TERMINALS!**
1	POW_SUP	Power	Power supply positive (DC bus).	 Power pins can have high voltages > 50 V, always respect clearance and creepage requirements (Typ > 0.25 mm)! Dimension PCB traces and connectors according to the current of the application!
2	GND_P		Power supply negative (Power Ground).	
Chassis	PE		Protective Earth connected to driver housing and fixing M2.5 threads.	Ensure basic insulation (Min > 0.5 mm) between protective earth and other live circuits.

P2 Motor Power pins				
Pin	**Name**	**Type**	**Function**	**WARNING, POWER TERMINALS!**
1	PH_A	Power	Motor phase A for 3-phase motors, positive for DC motors.	 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	PH_B		Motor phase B for 3-phase motors, negative for DC motors.	
3	PH_C		Motor phase C for 3-phase motors (do not connect for DC motors).	
Chassis	PE		Protective Earth connected to driver housing and fixing M2.5 threads.	Ensure basic insulation (Min > 0.5 mm) between protective earth and other live circuits.

Capitan CORE power pins	**Recommended mating contact**	**Description**
	Up to 11.2 A_{RMS} rated motors	
Ø 1.52 mm, 4 mm pitch, gold plated power pins.	 Mill-Max 9801-0-15-15-23-27-10-0	Beryllium copper TH pin receptacle. Gold plated. PCB hole 2.549 mm. Maximum current 11.2 A.
	> 11.2 A_{RMS} rated motors	
	Direct solder to PCB. TH pad with min. hole Ø 1.63 mm. Ensure PCB tracks are wide enough to withstand the target current.	
Chassis (aluminum body)		
3 mm board-to-board height spacers.	 Wurth Electronics 9774030951R	Surface-mount tinned steel round spacer, Ø 2.7 mm internal, Ø 5.1 mm external, 3 mm board-to-board height.
	 Ettinger 05.52.033	Unattached nickel-plated brass round spacer, Ø 2.6 mm internal, Ø 4.5 mm external, 3 mm board-to-board height.

5.3. P3 Feedback connector

The pinout of the Feedback connector is exactly the same for Capitan CORE (CAP_CORE) and **Capitan NET** (CAP_NET) although **the position of the connector is different**.



P3 Feedback connector							
#	**Signal name**	**Description**	**Type**	**#**	**Signal name**	**Description**	**Type**
1	GND_A	Analog Ground. If no external analog circuits are used, do not connect this pin at all. If used, do not connect this pin to GND_D directly. Instead, use a ferrite bead or 1 Ω resistor in between.	Power	**2**	GND_A	Analog Ground. If no external analog circuits are used, do not connect this pin at all. If used, do not connect this pin to GND_D directly. Instead, use a ferrite bead or 1 Ω resistor in between.	Power
3	DNC	Reserved. Do not connect (leave floating).	-	**4**	AN1_P	Analog input 1. Can be used as a command source or for torque sensing.	16 bit differential analog input
5	DNC			**6**	AN1_N		
7	DNC			**8**	AN2_P	Analog input 2. Can be used as a command source or for torque sensing.	
9	DNC			**10**	AN2_N		
11	DNC			**12**	DNC	Reserved. Do not connect (leave floating).	-

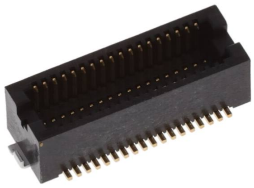
13	MOTOR_TEMP	Motor temperature sensor input. 0 V to 5 V level high impedance input.	12 bit single-ended analog input	**14**	DNC		
15	GND_D	Digital signal Ground.	Power	**16**	NC	Internally not connected. Recommended to leave them unconnected.	
17	HALL_1	Digital hall 1.	Input, 3.3 V level single-ended.	**18**	NC		
19	HALL_2	Digital hall 2.		**20**	GND_A	Analog Ground. If no external analog circuits are used, do not connect this pin at all. If used, do not connect this pin to GND_D directly. Instead, use a ferrite bead or 1 Ω resistor in between.	Power
21	HALL_3	Digital hall 3.		**22**	GND_D	Digital signal Ground.	
23	CLL	Reserved. Must be tied or pulled-down to GND_D.	-	**24**	DIG_ENC_1A	Incremental encoder 1 A.	Input, 3.3 V level single-ended.
25	CHL	Reserved. Must be tied or pulled-up to 3.3 V.		**26**	DIG_ENC_1B	Incremental encoder 1 B.	
27	CLL	Reserved. Must be tied or pulled-down to GND_D.		**28**	DIG_ENC_1Z	Incremental encoder 1 Index.	
29	CHL	Reserved. Must be tied or pulled-up to 3.3 V.		**30**	DIG_ENC_2A	Incremental encoder 2 A.	

31	DNC	Reserved. Do not connect (leave floating).		**32**	DIG_ENC_2B	Incremental encoder 2 B.	
33	DNC			**34**	DIG_ENC_2Z	Incremental encoder 2 Index.	
35	DNC			**36**	GND_D	Digital signal Ground.	Power
37	DNC			**38**	ABSENC1_CLK	Clock output for Absolute Encoder 1.	Output
39	DNC			**40**	ABSENC1_DATA	Data input for Absolute Encoder 1 (supports SSI or up to 2 BiSS-C encoders connected in daisy chain topology).	Input
41	DNC			**42**	DNC	Reserved. Do not connect (leave floating).	-
43	DNC			**44**	GND_D	Digital signal Ground.	Power
45	DNC			**46**	DNC	Reserved. Do not connect (leave floating).	-
47	DNC			**48**	DNC		
49	DNC			**50**	DNC		
51	DNC			**52**	DNC		
53	DNC			**54**	DNC		
55	DNC			**56**	DNC		
57	DNC			**58**	DNC		
59	GND_D	Digital signal Ground.	Power	**60**	GND_D	Digital signal Ground.	Power

Notes and naming conventions:

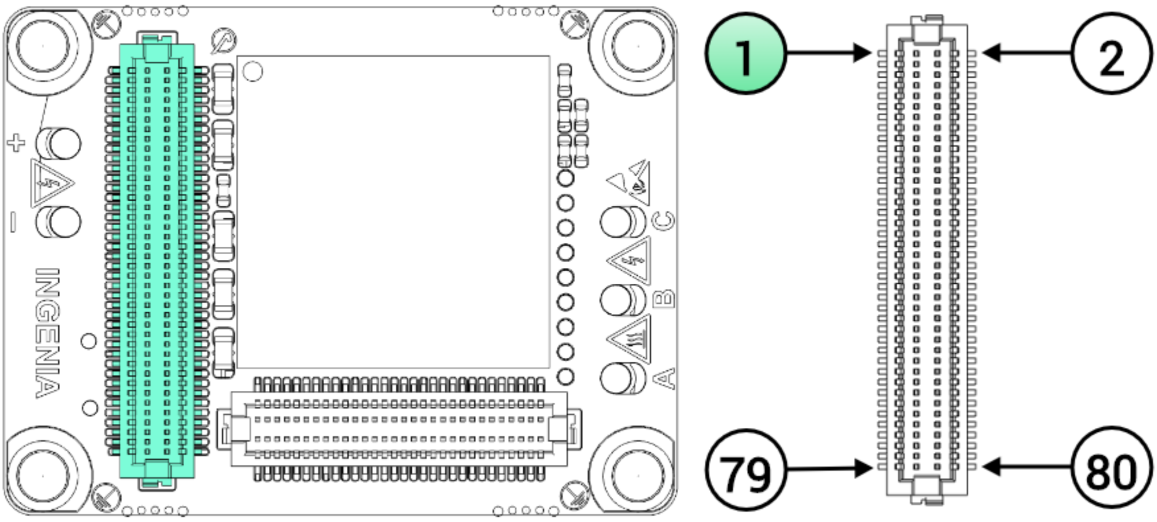
- All pins are tolerant to 3.3 V unless otherwise noted.
- Unused digital outputs should be left unconnected.
- Unused digital inputs should be connected to GND_D.
- Unused analog inputs should be connected to 1.65V_REF.
- "_P" and "_N" indicates positive and negative terminals of differential signals

- "\" 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	Capitan CORE connector	Required mating connector	Description
Hirose Electric	 DF12NB(3.0)-60DP-0.5V(51)	 DF12NB(3.0)-60DS-0.5V(51)	60-pin mezzanine stacking board connector. 0.5 mm pitch. Center strip, gold-plated surface mount contacts. 3 mm stacking height. Hirose DF12 connectors operation and storage temperature, when mounted, is -45 °C to 125 °C.

5.4. P4 Capitan CORE Interface connector

Although using the same physical connector as Capitan NET (CAP-NET), position and pinout are different in Capitan CORE (CAP-CORE).



P4 Capitan CORE 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	5V_D	5 V, 300 mA continuous logic supply input. Must be low ripple and ensure ±2% regulation tolerance or less. It is advised to connect all four 5V_D pins. It is recommended to provide at least 500 mA input current if pins 9 or 10 (3.3V_D) are used to drive external circuits. The rise time of the 5 V supply must be between 2 ms and 10 ms to guarantee a proper initialization.	Power input	**4**	5V_D	5 V, 300 mA continuous logic supply input. Must be low ripple and ensure ±2% regulation tolerance or less. It is recommended to connect all four 5V_D pins. It is advised to provide at least 500 mA input current if pins 9 or 10 (3.3V_D) are used to drive external circuits. The rise time of the 5 V supply must be between 2 ms and 10 ms to guarantee a proper initialization.	Power input
5	5V_D			**6**	5V_D		
7	GND_D	Digital signal Ground.	Power	**8**	GND_D	Digital signal Ground.	Power
9	3.3V_D	3.3 V, 250 mA max. output to supply peripherals. Excessive current demand on this pin could cause failure or even permanent damage to the Capitan CORE.	Power output	**10**	3.3V_D	3.3 V, 250 mA max. output to supply peripherals. Excessive current demand on this pin could cause failure or even permanent damage to the Capitan CORE.	Power output
11	GND_D	Digital signal Ground.	Power	**12**	GND_D	Digital signal Ground.	Power
13	GND_D			**14**	MCB_SPI_MISO	Motion Control Bus, Master input Slave output	Output
15	GND_D			**16**	MCB_SPI_MOSI	Motion Control Bus, Master output Slave input	Input
17	GND_D			**18**	\MCB_SPI_CS	Motion Control Bus, Chip Select input	
19	GND_D			**20**	MCB_SPI_CLK	Motion Control Bus, Clock input	
21	GND_D			**22**	MCB_SYNC0	Motion Control Bus, synchronization signal 0	
23	GND_D			**24**	MCB_SYNC1	Motion Control Bus, synchronization signal 1. It is strongly suggested to pull-up this signal to 3.3V with a 10 kΩ resistor.	Output
25	GND_D			**26**	MCB_IRQ	Motion Control Bus, interrupt request output. Add a pull-down resistor 10 kΩ to this pin.	
27	GND_D			**28**	DNC	Reserved. Do not connect (leave floating).	-

29	NC	Internally not connected. Recommended to leave them unconnected.	-	**30**	GND_D	Digital signal Ground.	Power
31	NC			**32**	GND_D		
33	\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	**34**	\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
35	DNC	Reserved. Do not connect (leave floating).	-	**36**	DNC	Reserved. Do not connect (leave floating).	-
37	FAULT_SIGNAL	Fault state signaling output. Can directly drive a (typically) red LED anode at 3.3 V up to 3 mA.	Output	**38**	\HW_RESET	Capitan CORE reset input. Keeps the motion controller disabled with low power consumption. A minimum low-level pulse of 100 µs is needed for resetting Capitan CORE. 2 kΩ pull-up to 3.3 V is internally included.	Input
39	GND_D	Digital signal Ground.	Power	**40**	DNC	Reserved. Do not connect (leave floating).	-
41	\EXT_FAULT	External fault input. Could be configured to force the Capitan CORE state-machine to the Fault state (motor will be stopped) when the pin is driven to 0 V. Includes an internal weak pull-up, although external pull-up to 3.3 V is advised.	Input	**42**	PWM_BRAKE	PWM output for driving a mechanical brake. Configurable up to 40 kHz. A high level indicates the motor is free to move. Add a 10 kΩ ~ 47 kΩ pull-down resistor to this pin to ensure the brake is always in a safe state during boot-up or reset situations when this pin might be in high impedance.	Output
43	GPO4	Digital Output 4.	Output	**44**	DNC	Reserved. Do not connect (leave floating).	-
45	DNC	Reserved. Do not connect (leave floating).	-	**46**	DNC		
47	GPI1	Digital Input 1.	Input	**48**	DNC		
49	GPI2	Digital Input 2.		**50**	ABSENC2_CLK	Clock output for Absolute Encoder 2.	Output
51	ABSENC2_DATA	Data input for Absolute Encoder 2 (supports SSI only)		**52**	DNC	Reserved. Do not connect (leave floating).	-

53	GPI3	Digital Input 3.		**54**	DNC		
55	GPO1	Digital Output 1.	Output	**56**	GPO2	Digital Output 2.	Output
57	GPO3	Digital Output 3.		**58**	GPI4	Digital Input 4.	Input
59	GND_D	Digital signal Ground.	Power	**60**	GND_D	Digital signal Ground.	Power
61	DNC	Reserved. Do not connect (leave floating).	-	**62**	DNC	Reserved. Do not connect (leave floating).	-
63	DNC			**64**	DNC		
65	DNC			**66**	DNC		
67	GND_D	Digital signal Ground.	Power	**68**	GND_D	Digital signal Ground.	Power
69	NC	Internally not connected. Recommended to leave them unconnected.	-	**70**	NC	Internally not connected. Recommended to leave them unconnected.	-
71	NC			**72**	NC		
73	NC			**74**	NC		
75	1.65V_REF	1.65 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 of Capitan CORE: route by following the best layout practices.	Power output	**76**	NC		
77	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 of Capitan CORE: route by following the best layout practices.		**78**	DNC	Reserved. Do not connect (leave floating).	
79	GND_A	Analog Ground. If no external analog circuits are used, do not connect this pin at all. If used, do not connect this pin to GND_D directly. Instead, use a ferrite bead or 1 Ω resistor in between.	Power	**80**	GND_A	Analog Ground. If no external analog circuits are used, do not connect this pin at all. If used, do not connect this pin to GND_D directly. Instead, use a ferrite bead or 1 Ω resistor in between.	Power

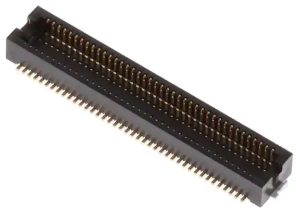
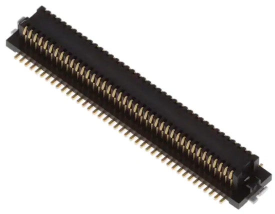
Notes and naming conventions:

- 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.

Motion Control Bus

Capitan CORE can be controlled as a slave by means of its proprietary **Motion Control Bus** (MCB). Check how in the **Summit Series Reference Manual**.

Manufacturer	Capitan CORE connector	Required mating connector	Description
Hirose Electric	 DF12NB(3.0)-80DP-0.5V(51)	 DF12NB(3.0)-80DS-0.5V(51)	80-pin mezzanine stacking board connector. 0.5 mm pitch. Center strip, gold-plated surface mount contacts. 3 mm stacking height. Hirose DF12 connectors operation and storage temperature, when mounted, is -45°C to 125°C.

6. Safe Torque Off (STO)

The Safe Torque Off (STO) is a functional safety system that prevents motor torque in an emergency event while Capitan CORE 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 Capitan CORE 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 Capitan CORE 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	2.42×10^{-11} 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 26.4 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 26.4 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; 26.4 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 26.4 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.	
Uncontrolled Motor Movement	ⓘ **Uncontrolled Motor Movement** In the event of a failure in the power stage, **the motor shaft may rotate up to 180° electrical degrees.** It is responsibility of the customer to prevent any hazards related ot this unexpected motor movement.	

<table>
<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 °C to 85 °C</td></tr>
<tr><td>Storage Temperature</td><td>-40 °C to 100 °C</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>
<tr><td>Environmental</td><td colspan="2">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</td></tr>
</table>

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 Capitan CORE to be connected to a brushless motor.

Procedure Step	Action
1	Power on the Capitan CORE 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 Capitan CORE supply and remain in this state for more than 10 seconds.
12	Power on the Capitan CORE with STO1= low, STO2 = high. Remain in this state more than 3.4 seconds.
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 Capitan CORE supply and remain in this state for more than 10 seconds.
20	Power on the Capitan CORE with STO1= high, STO2 = high.
21	Try to perform a "Motor Enable" (using Motionlab 3 or network commands).

Procedure Step	Action
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

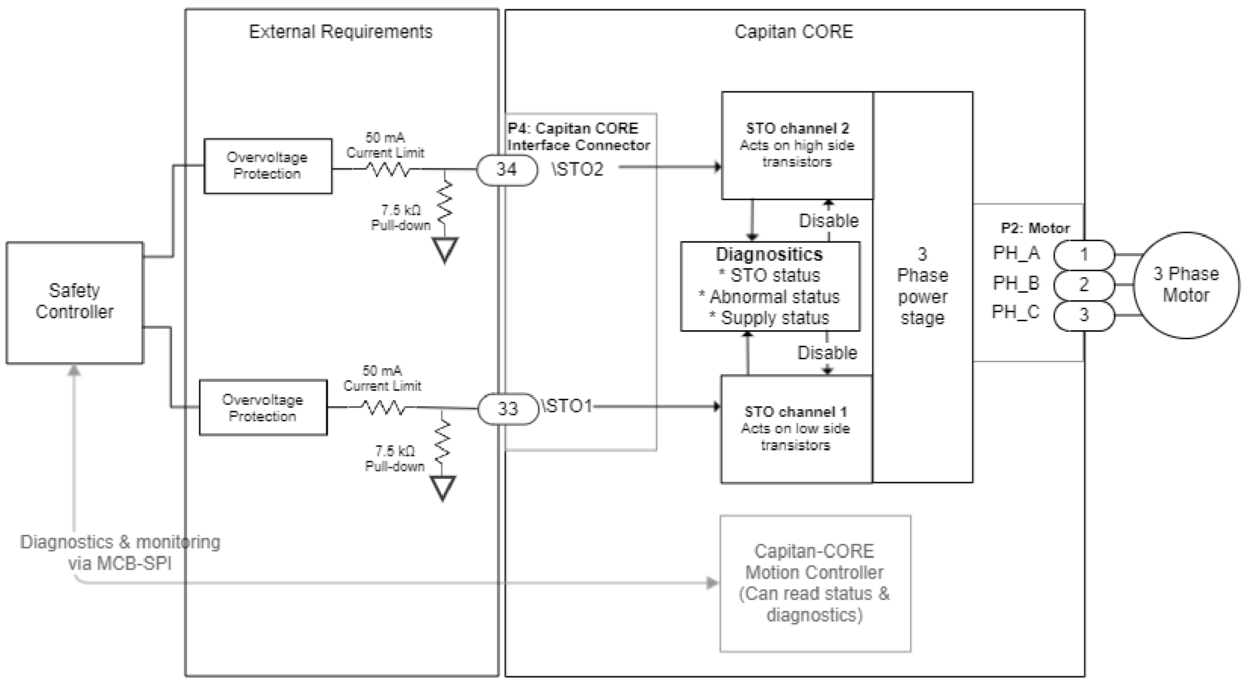
The truth table of the STO inputs is shown next indicating the different states of the system:

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.
	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.

Mode	State	STO1 status / level		STO2 status / level		Power stage status	STO report bit status	STO abnormal fault	State description
	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.

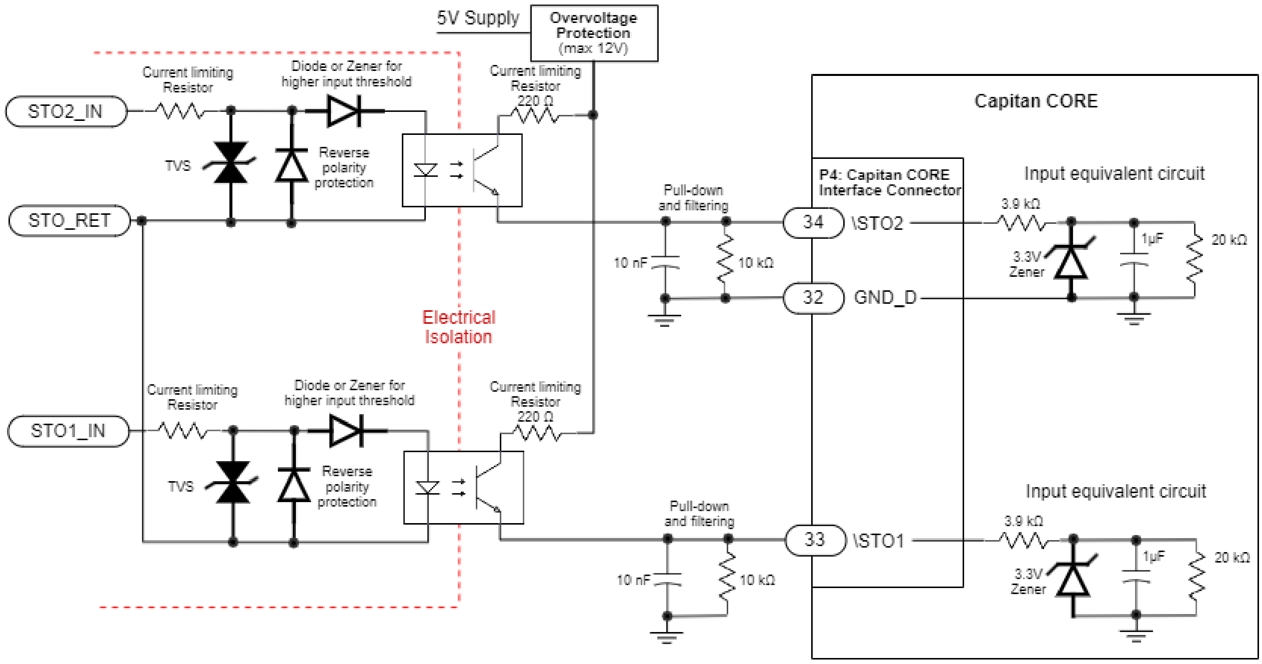
6.5. STO Inputs External Requirements

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.

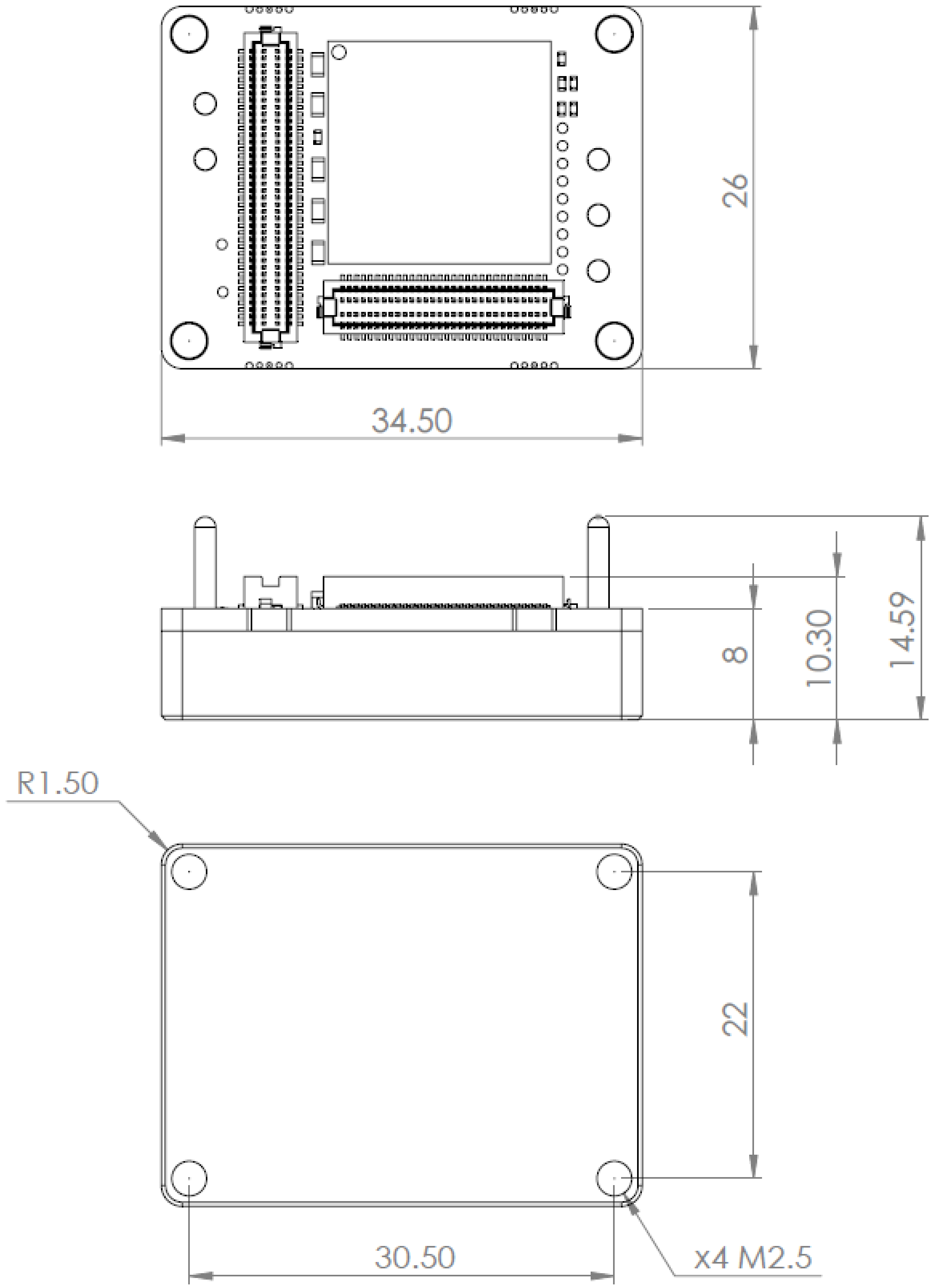
7. Dimensions

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

Drawings shown below could be download here.

3D Model

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


26
34.50
8
10.30
14.59
R1.50
22
30.50
x4 M2.5

8. Installation

8.1. Unboxing

When unboxing the drive please ensure the following:

- Remove it from the bag carefully.
- Check that there is no visible physical damage. If any, report it immediately to the carrier.
- Check the part number of the drive on the side label.

8.2. Installation Safety Requirements

The drive has live circuits that can be touched and entail **a risk of electric shock** (*Protective Class 0*), as well as **a risk of thermal injury**. It must be mounted on a closed electrical operating area to which access is restricted to skilled or instructed personnel. This enclosure, cabinet, protection, or case should have a minimum Index of Protection of IP3X. To ensure electrical safety it is also important that the environment is clean from conductive pollution or condensation when the drive is powered (Pollution degree 2).

	**WARNING HOT SURFACES!** The drive and motor can become hot and cause severe burns. If any of the user-accessible surfaces exceeds 70 °C, a hot-surface signal must be added. This is the responsibility of the installer.
	**DANGER, ELECTRIC SHOCK!** Power and motor pins have live voltages which can exceed 50 V which can cause electric shock! Perform installation procedures without voltage. Ensure the drive is mounted on a closed electrical operating area which protects against direct contact.

The drive may be operated without enclosure and protection against electric shock when it is supplied at Extra Low Voltage (ELV), ≤ 50 V.

8.3. Mounting the Drive to a Heatsink or Cooling Plate

The drive has 4x M2.5 threaded holes with a max. thread depth of 4.5 mm for assembling the Capitan XCR to a cooling plate or heatsink. See Dimensions section for further details. Assembling the drive correctly is essential to:

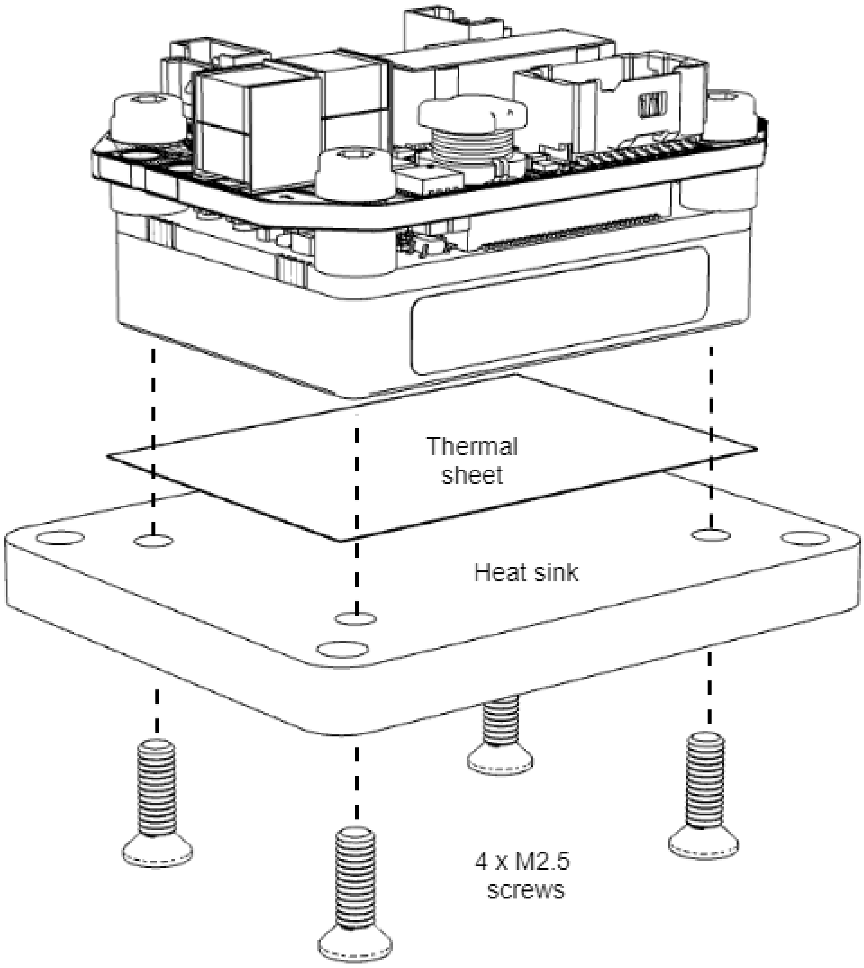
1. Provide a conduction heat dissipation path. Please see the Thermal and Power Specifications section in the Product Description chapter to determine your heat dissipation needs.
2. Ensure electrical conduction between the drive and Protective Earth, chassis, or the motor enclosure. This is strongly recommended for EMC and electrical safety.
3. Secure the drive in place to prevent any damage.

8.3.1. Back Installation

The preferred way to assemble the drive is from the back using a thermal interface tape and 4 x M2.5 screws. Thermal tapes and materials offer a clean and repetitive way to improve the heat transfer from the drive to the heat sink. There are several thermal interface alternatives, some suggested part numbers are T-Global Technology

LI98-1140-27-0.25, Berquist Bond-Ply 100 series, t-Global Technology GT30S, or copper conductive tape CCH-18-101-0100. To install the drive, follow these steps:

1. Ensure the bottom surface of the drive and the heatsink are clean and dry. Isopropyl alcohol (isopropanol) applied with a lint-free wipe or swab should be adequate for removing surface contamination such as dust or fingerprints. Do not use “denatured alcohol” or glass cleaners which often contain oily components. Allow the surface to dry for some minutes before applying the tape. More aggressive solvents (such as acetone, methyl ethyl ketone (MEK) or toluene) may be required to remove heavier contamination (grease, machine oils, solder flux, etc.) but should be followed by a final isopropanol wipe as described above. Note:- Be sure to read and follow the manufacturers’ precautions and directions when using primers and solvents.
2. Cut a 34 mm x 27 mm piece of the thermal tape.
3. Apply the tape to the bottom of the drive at a modest angle with the use of a squeegee, rubber roller, or finger pressure to help reduce the potential for air entrapment under the tape during its application. The liner can be removed after positioning the tape onto the first substrate.
4. Assemble the drive to the heatsink ensuring alignment to the holes by applying compression to ensure good wetting of the substrate surfaces with the tape. Proper application of pressure ~ 5 kg and time (> 5 s) is crucial for the best thermal performance as the surface adhesive will have better wetting. A twisting motion during assembly will improve wetting. This should be a back and forth twisting motion during the application of compression. Moderate heat (<85°C) can be employed to increase the wetting percentage and wetting rate of the substrates and to build room temperature bond strength.
5. Screw the 4 x M2.5 screws applying between 0.17 and 0.3 Nm of torque. Note that the M2.5 thread should be handled gently. The threads may penetrate the thermal interface material if the corners have not been trimmed.



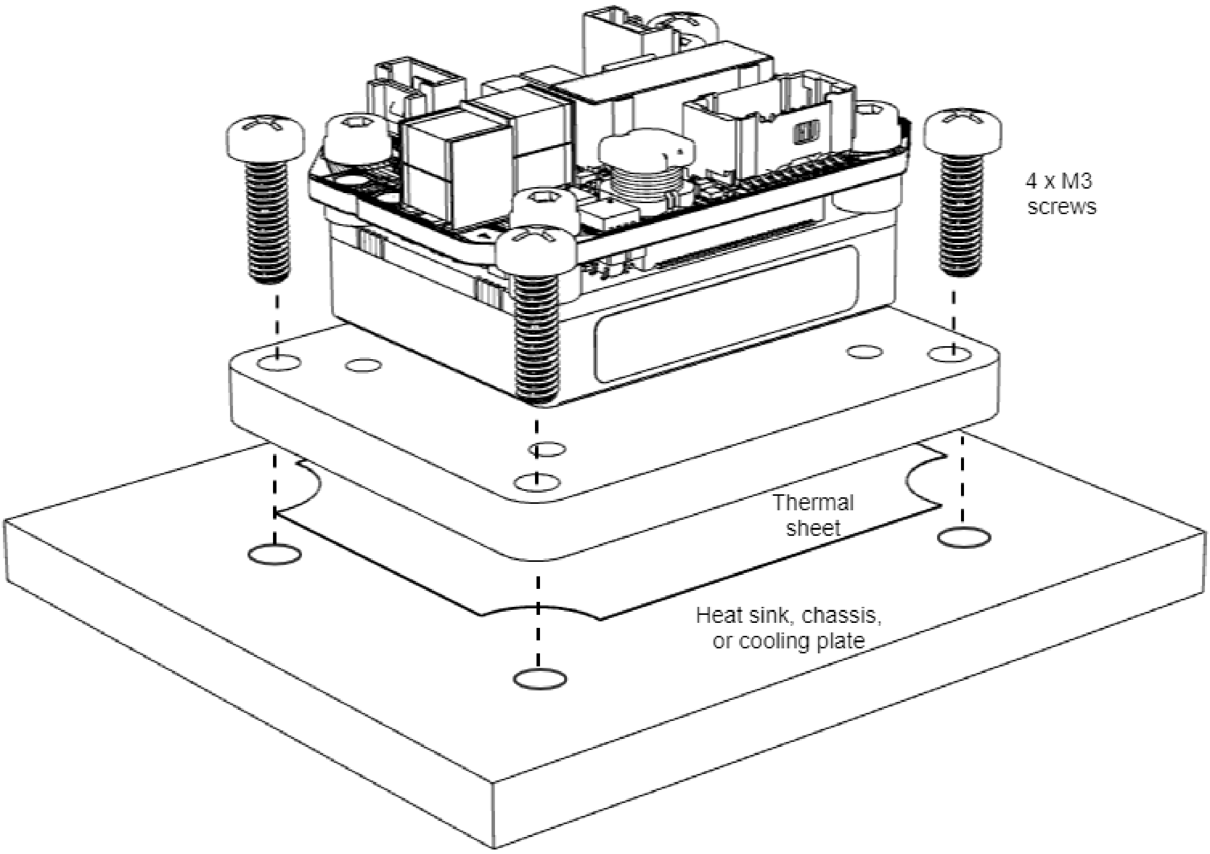
For best power and thermal performance (high current and voltage application), thermal grease, pastes, or silicone are recommended. The best thermal material tested is ARCTIC MX-4. Chemtronics CW7250 (white paste non-conductive) and Chemtronics CW7100 (silver-based, conductive) also offer good results.

Mounting the drive without a thermal interface material is also acceptable for low power applications since any imperfection on the heatsink or case surfaces will create air bubbles that would reduce the heat transfer.

8.3.2. Front Installation

Front installation can be done using a Flat heatsink together with the thermal tape and 4 x M2.5 x 8 DIN965 screws.

1. Assemble the drive to the flat heatsink following the Back Installation process.
2. Use appropriate thermal interface material between the previously cleaned Flat Heatsink and the other surface.
3. Screw using M3 screws with appropriate torque according to the base material.



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