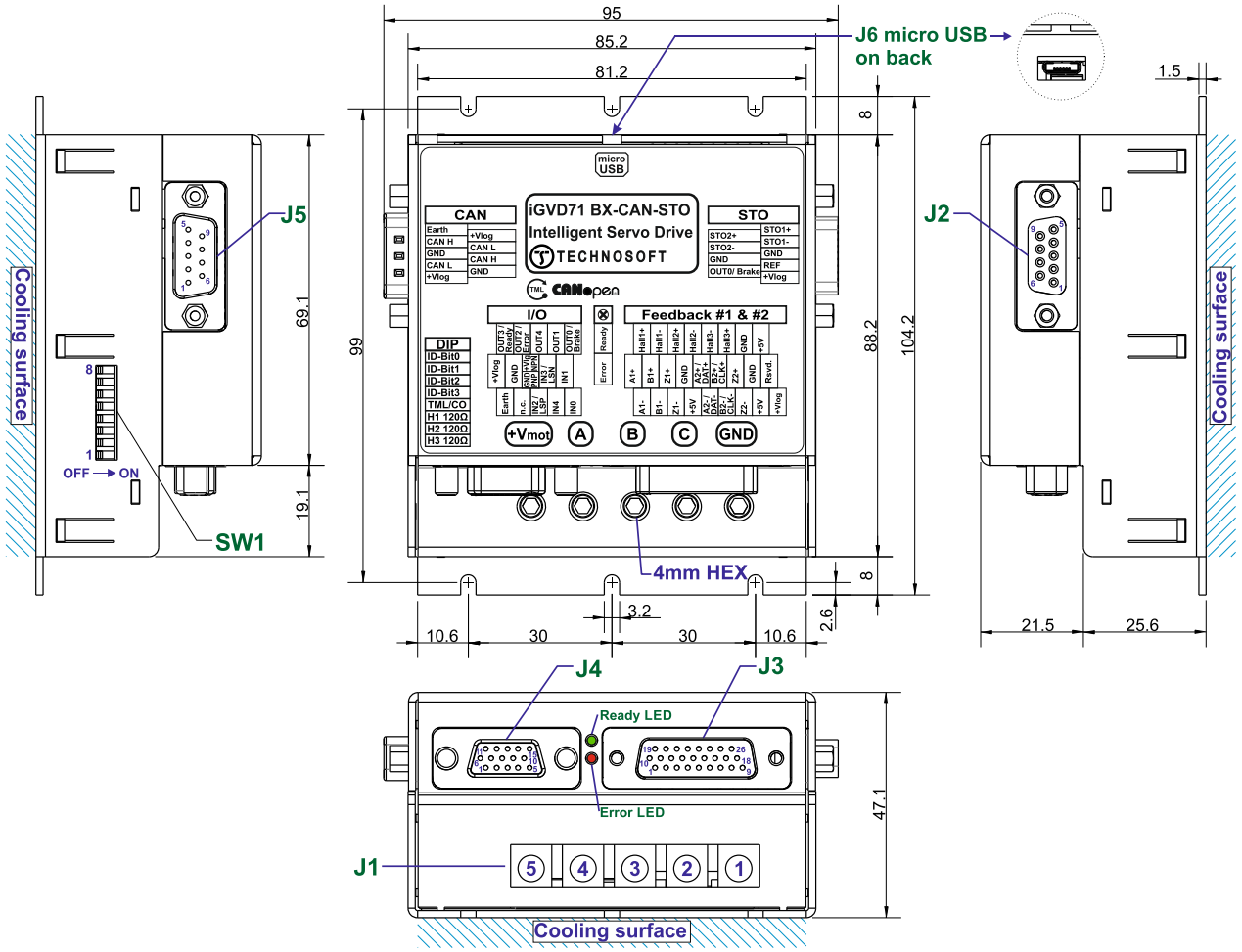

All dimensions are in mm; Drawing not to scale.

Motor – sensor configurations			
Motor / Sensor	PMSM	BLDC	DC BRUSH
Incr. Encoder	✓		✓
Incr. Encoder + Hall	✓	✓	
SSI	✓	✓	✓
BiSS-C	✓	✓	✓
EnDAT*	✓	✓	✓
Tacho			✓

**Available Starting with F514K firmware version*

- **Features**
- Motion controller and drive in a single compact unit based on MotionChip™ technology
- Universal solution for control of rotary and linear brushless and brushed motors
- Advanced motion control capabilities (PVT, S-curve, electronic cam)
- Motor supply: 11-80V; Logic supply[1]: 9-36V
- Output current[2]:
  - Nominal: 71 A_{RMS} / 100A amplitude
  - Peak: 100 A_{RMS} / 140A amplitude
- [3]STO: 2 safe torque-off inputs, 18-36V SELV/PELV supply, safety integrity level (SIL3) acc. to EN61800-5-1; -2/ EN61508-3; -4/ EN ISO 13849-1.
- 5x opto-isolated digital inputs, 12-36V, PNP/NPN compatible: 2 for limit switches, 3 general-purpose
- 4x digital outputs, 0.2A PNP/ 0.3A NPN software selectable: Ready, Error, 2 general-purpose
- 1x PNP/NPN 2A Motor brake digital output: Out0/Brake
- 1x analogue input: 12-bit, 0-5V: Reference, Feedback or general purpose
- Feedback Devices (dual-loop support)
  - 1st feedback devices supported:
    - Incremental encoder interface (differential)
  - 2nd feedback devices supported:
    - Incremental encoder interface (differential)
    - BISS C / SSI / EnDAT 2.2* encoder interface
- Digital Hall sensor interface (single-ended and open collector or differential, selectable by DIP switch)
- Pulse & direction reference (differential) capability
- [4]USB
- CAN-bus 2.0B interface
- 16 h/w addresses selectable by DIP switch
- TMLCAN and CANopen (CiA 301, CiA 305 and CiA 402) protocols selectable by DIP switch
- 16k x 16 SRAM memory for data acquisition
- 16k x 4 E^2ROM to store setup data, TML motion programs, cam tables and other user data
- Operating ambient temperature: 0-40°C (over 40°C with derating)

[1] Logic supply must be SELV/ PELV type (Safety Extra Low Voltage / Protective Extra Low Voltage)
[2] Nominal output current possible only with external radiator (not included) that can maintain lower plate temperature below 75ºC; The radiator is mounted under the drive using thermal paste or direct metal contact. Its size is application dependent
[3] The STO circuit must be supplied with minimum 18V to enable PWM output
[4] Micro USB cable not provided

Mating Connectors		
Ref	**Component**	**Function**
J1	High AMP wire. 4mm HEX socket. AWG 6-16 wire gauge. Strip: - min 8 mm for cables with isolation diameter less than 6.5 mm; - min 12 mm/ max 15 mm for cables with isolation diameter bigger than 6.5 mm.	Motor Phases Motor Supply
	Avoid generating metal debris/ filings into drive from the wire leads! **In case of multi-stranded wires, a proper crimp ferrule* must be used as wire terminal.**	
J2	generic 9-pin Sub-D male	STO OUT0/Brake Analog Ref
J3	generic 26-pin High Density D-Sub male	Feedback #1 Feedback #2 Digital Halls
J4	generic 15-pin High Density D-Sub male	I/O
J5	generic 9-pin Sub-D female	CAN
J6	Standard Micro USB cable	Communication

* For more recommendations about wires and ferrules, check the User Manual of the drive.

Connectors Description

	Pin	Name	Type	Description
J1	**1**	**GND**	-	Negative return (ground) of the power supply
	2	**C**	**O**	**Phase C** for 3-ph motors
	3	**B**	**O**	**Phase B** for 3-ph motors, Motor- for DC brush motors
	4	**A**	**O**	**Phase A** for 3-ph motors, Motor+ for DC brush motors
	5	**+V_{MOT}**	**I**	Positive terminal of the motor supply: 11 to 80V_{DC}.

	Pin	Name	Type	Description
J2	**1**	**+V_{LOG}**	**I**	Positive terminal of the logic supply: 9 to 36V_{DC}. Internally connected to other +Vlog pins.
	2	**REF**	**I**	Analogue input, 12-bit, 0-5V. Used to read an analog position, speed or torque reference, or used as general-purpose analogue input
	3	**GND**	**-**	Negative return (ground)
	4	**STO1-**	**I**	Safe Torque Off input 1, negative return (opto-isolated, 18÷36V)
	5	**STO1+**	**I**	Safe Torque Off input 1, positive input (opto-isolated, 18÷36V)
	6	**OUT0/Brake**	**O**	Digital output used for an electro-mechanical brake,12-36V, 2A PNP/ 2A NPN software selectable
	7	**GND**	**-**	Negative return (ground)
	8	**STO2-**	**I**	Safe Torque Off input 2, negative return (opto-isolated, 18÷36V)
	9	**STO2+**	**I**	Safe Torque Off input 2, positive input (opto-isolated, 18÷36V)

	Pin	Name	Type	Description
J5	**1&9**	**+V_{LOG}**	**I**	Positive terminal of the logic supply: 9 to 36V_{DC}. Internally connected to other +Vlog pins.
	2&8	**CAN L**	**I/O**	CAN-Bus negative line (dominant low)
	3&6	**GND**	**-**	Negative return (ground)
	4&7	**CAN H**	**I/O**	CAN-Bus positive line (dominant high)
	5	**Earth**	**-**	Earth connection; Internally connected to the metallic side of J2,3,4 and 5

	Pin	Name	Type	Description
J6		**USB**	-	Standard micro-USB port. Is identified in Windows as RS232 COM port.

	Pin	Name	Type	Description
J3	**1**	**A1-**	**I**	Incr. encoder1 A- diff. input
	2	**B1-**	**I**	Incr. encoder1 B- diff. input
	3	**Z1-**	**I**	Incr. encoder1 Z- diff. input
	4	**+$5V_{OUT}$**	**O**	5V output supply
	5	**A2- /Pulse-/ Data-/SL-**	**I**	Incr. encoder2 A- diff. input, or Pulse-, or Data- for SSI, or Slave- for BiSS; has internal 120Ω resistor between pins 5 and 14
	6	**B2-/Dir-/CLK-/MA-**	**I/O**	Incr. encoder2 B- diff. input, or Dir-, or Clock- for SSI, or Master- for BiSS; has internal 120Ω resistor between pins 6 and 15
	7	**Z2-**	**I**	Incr. encoder2 Z- diff. input; has internal 120Ω resistor between pins 7 and 16
	8	**+$5V_{OUT}$**	**O**	5V output supply for sensors usage
	9	**+V_{LOG}**	**I**	Positive terminal of the logic supply: 9 to 36V_{DC}. Internally connected to other +Vlog pins.
	10	**A1+/ Pulse**	**I**	Incr. encoder1 A+ diff. input, or Pulse
	11	**B1+/Dir**	**I**	Incr. encoder1 B+ diff. input, or Dir
	12	**Z1+**	**I**	Incr. encoder1 Z+ diff. input
	13	**GND**	**-**	Return ground for sensors supply
	14	**A2+/Pulse+/ Data+/SL+**	**I**	Incr. encoder2 A+ diff. input, or Pulse+, or Data+ for SSI, or Slave+ for BiSS; has internal 120Ω resistor between pins 5 and 14
	15	**B2+/Dir+/CLK +/MA+**	**I/O**	Incr. encoder2 B+ diff. input, or Dir+, or Clock+ for SSI, or Master+ for BiSS; has internal 120Ω resistor between pins 6 and 15
	16	**Z2+**	**I**	Incr. encoder2 Z+ diff. input; has internal 120Ω resistor between pins 7 and 16
	17	**GND**	**-**	Return ground for sensors supply
	18	**n.c.**		not connected
	19	**Hall 1+**	**I**	Digital input Hall 1+ diff. sensor input; SW1 pin 3 can connect an 120Ω resistor between pins 19 and 20
	20	**Hall 1-**	**I**	Digital input Hall 1- diff. sensor input; SW1 pin 3 can connect an 120Ω resistor between pins 19 and 20
	21	**Hall 2+**	**I**	Digital input Hall 2+ diff. sensor input; SW1 pin 2 can connect an 120Ω resistor between pins 21 and 22
	22	**Hall 2-**	**I**	Digital input Hall 2- diff. sensor input; SW1 pin 2 can connect an 120Ω resistor between pins 21 and 22
	23	**Hall 3-**	**I**	Digital input Hall 3- diff. sensor input; SW1 pin 1 can connect an 120Ω resistor between pins 23 and 24
	24	**Hall 3+**	**I**	Digital input Hall 3+ diff. sensor input; SW1 pin 1 can connect an 120Ω resistor between pins 23 and 24
	25	**GND**	**-**	Return ground for sensors supply
	26	**+$5V_{OUT}$**	**O**	5V output supply

	Pin	Name	Position	Description
SW1	**1**	**H3 120Ω**	**up (ON)**	Internally connect an 120Ω termination resistor between Hall 3+ and Hall 3- pins
	2	**H2 120Ω**	**up (ON)**	Internally connect an 120Ω termination resistor between Hall 2+ and Hall 2- pins
	3	**H1 120Ω**	**up (ON)**	Internally connect an 120Ω termination resistor between Hall 1+ and Hall 1- pins
	4	**TML/CO**	**up (ON)**	Select CANopen communication protocol
			down (OFF)	Select TMLCAN communication protocol
	5	**ID-Bit3**	-	Hardware AxisID selection switches They represent the first 4 LSB bits of an 8-bit Axis ID number. When all bits are 0 then AxisID=255; If AxisID = 255 in CANopen, the drive will be in "LSS inactive" state and the Green LED will flash at 1 second intervals
	6	**ID-Bit2**	-	
	7	**ID-Bit1**	-	
	8	**ID-Bit0**	-	

	Pin	Name	Type	Description
J4	1	Earth	-	Earth connection; Internally connected to the metallic side of J2,3,4 and 5
	2	n.c.	-	not connected
	3	IN2/LSP	I	12-36V digital PNP/NPN opto-isolated input. Positive limit switch function
	4	IN4	I	12-36V general-purpose digital PNP/NPN opto-isolated input.
	5	IN0	I	12-36V general-purpose digital PNP/NPN opto-isolated input.
	6	$+V_{LOG}$	I	Positive terminal of the logic supply: 9 to $36V_{DC}$. Internally connected to other +Vlog pins.
	7	GND	-	Return ground for I/O pins
	8	GND PNP / +Vlog NPN	-	PNP/NPN Inputs type selector. Connect to GND to use inputs as PNP; Connect to +Vlog to use inputs as NPN
	9	IN3/LSN	I	12-36V digital PNP/NPN opto-isolated input. Negative limit switch function
	10	IN1	I	12-36V general-purpose digital PNP/NPN opto-isolated input.
	11	OUT3/Ready	O	12-36V drive Ready digital output, 0.2A PNP/ 0.3A NPN, software selectable
	12	OUT2/Error	O	12-36V drive Error digital output, 0.2A PNP/ 0.3A NPN, software selectable
	13	OUT4	O	12-36V general-purpose digital output, 0.2A PNP/ 0.3A NPN, software selectable
	14	OUT1	O	12-36V general-purpose digital output, 0.2A PNP/ 0.3A NPN, software selectable
	15	OUT0/Brake	O	Digital output used for an electro-mechanical brake,12-36V, 2A PNP/ 2A NPN software selectable

Electrical characteristics

All parameters measured under the following conditions (unless otherwise specified):

- V_{LOG} = 24 VDC; V_{MOT} = 80VDC
- Supplies start-up / shutdown sequence: -any-
- Load current (sinusoidal amplitude) = 100A

Operating Conditions		Min.	Typ.	Max.	Units
Ambient temperature		0		40[1,3]	ºC
Ambient humidity	Non-condensing	0		90	%Rh
Altitude / pressure[2]	Altitude (vs. sea level)	-0.1	0 ÷ 2.5	[2]	Km
	Ambient Pressure	0 [2]	0.75 ÷ 1	10.0	atm
Storage Conditions		**Min.**	**Typ.**	**Max.**	**Units**
Ambient temperature		-40		105	ºC
Ambient humidity	Non-condensing	0		100	%Rh
Ambient Pressure		0		10.0	atm
ESD capability (Human body model)	Not powered; applies to any accessible part			±0.5	kV
	Original packaging			±15	kV
Mechanical Mounting		**Min.**	**Typ.**	**Max.**	**Units**
External heatsink (cooling plate)	Current capability depends on heat transfer, heatsink dimension, cooling technique (natural or forced). Keep lower plate temperature at maximum 75ºC				

Environmental Characteristics		Min.	Typ.	Max.	Units
Size (Length x Width x Height)	Without mating connectors		104.2 x 95 x 47.1		mm
			~4.1 x 3.74 x 1.85		inch
Weight	Without mating connectors		300		g
Power dissipation	Idle (no load)		3		W
	Operating		80÷100		
Efficiency			98		%
Cleaning agents	Dry cleaning is recommended	Only Water- or Alcohol- based			
Protection degree	According to IEC60529, UL508	IP20			-

Logic Supply Input ($+V_{LOG}$)		Min.	Typ.	Max.	Units
Supply voltage	Nominal values	12	24	36	V_{DC}
	Absolute maximum values, drive operating but outside guaranteed parameters	8	24	40	V_{DC}
	Absolute maximum values, surge (duration ≤ 10ms) †	-1		+45	V
Supply current	$+V_{LOG}$ = 12V		170		mA
	$+V_{LOG}$ = 24V		110		
	$+V_{LOG}$ = 36V		90		
Motor Supply Input ($+V_{MOT}$)		**Min.**	**Typ.**	**Max.**	**Units**
Supply voltage	Nominal values	12	80	90	V_{DC}
	Absolute maximum values, drive operating but outside guaranteed parameters	11		94	V_{DC}
	Absolute maximum values, surge (duration ≤ 10ms) †	-1		95	V
Supply current	Idle		1	5	mA
	Operating	-130	±100	+130	A
	Absolute maximum value, short circuit condition (Duration ≤ 10ms) †			140	A
Motor Outputs (A/A+, B/A-, C/B+, BR/B-)		**Min.**	**Typ.**	**Max.**	**Units**
Nominal (recommended) output current, continuous[3] *As long as drive lower plate does not exceed 75ºC	for DC brushed and BLDC motors with Hall-based trapezoidal control			86.6	A
	for PMSM motors with FOC sinusoidal control (sinusoidal amplitude value)			100	
	for PMSM motors with FOC sinusoidal control (sinusoidal effective value)			70.7	A_{RMS}
Motor output current, peak	*As long as drive back plate does not exceed 75ºC	-135		+135	A
Short-circuit protection threshold				±140	A
Short-circuit protection delay		5	10		µs
On-state voltage drop	Nominal output current; including typical mating connector contact resistance		±0.3	±0.5	V
Off-state leakage current			±0.5	±1	mA
Motor inductance (phase-to-phase)	Recommended value, for current ripple max. ±5% of full range; $+V_{MOT}$ = 60 V	F_{PWM}			µH
		20 kHz	300		
		40 kHz	150		
		60 kHz	100		
		80 kHz	75		
	Minimum value, limited by short-circuit protection; $+V_{MOT}$ = 60 V	20 kHz	150		µH
		40 kHz	75		
		60 kHz	50		
		80 kHz	38		
Motor electrical time-constant (L/R)	Recommended value for ±5% current measurement error	20 kHz	250		µs
		40 kHz	125		
		60 kHz	100		
		80 kHz	63		
Current measurement	FS = Full Scale accuracy		±4	±8	%FS
Digital Inputs – opto-isolated- (IN0, IN1, IN2/LSP, IN3/LSN, IN4)		**Min.**	**Typ.**	**Max.**	**Units**
Mode compliance	PNP (J4, pin8 connected to GND)	Connect digital input pin to +Vlog to change its state			
	NPN (J4, pin8 connected to +Vlog)	Connect digital input pin to GND to change its state			
Default state	Input floating (wiring disconnected)	Logic LOW			
Input voltage	Logic LOW	0		6	V
	Logic HIGH	11		36	
	Absolute maximum	-5		50	
Input current	Logic LOW	0		0.2	mA
	Logic HIGH	0.65	1.9	3.2	
	Absolute maximum	0		4	
Input frequency			2		kHz
Minimum pulse			500		µs
ESD protection	Human body model	±15			kV

[1] Operating temperature at higher temperatures is possible with reduced current and power ratings

[2] iGVD71 can be operated in vacuum (no altitude restriction), but at altitudes over 2,500m, current and power rating are reduced due to thermal dissipation efficiency.

[3] @20Khz F_{PWM}

Digital Outputs (OUT0/Brake,OUT1, OUT2, OUT3, OUT4)		Min.	Typ.	Max.	Units
Mode compliance		PNP 24V			
Default state	Not supplied (+VLOG floating or to GND)	High-Z (floating)			
	Normal operation	Logic "High"			
Output voltage	Logic "HIGH"; output current = 0.2A		V_{LOG}-0.2	V_{LOG}-0.8	V
	Logic "LOW"; output current = 0, no load	open-collector			
	Logic "HIGH", external load to GND		0		
	Absolute maximum, continuous	-0.3		V_{LOG}+0.3	
	Absolute maximum, surge (duration ≤ 1s) †	-0.5		V_{LOG}+0.5	
Output current	Logic "HIGH", source current, continuous	OUT1,2,3,4		0.2	A
		OUT0/Brake		2	
	Logic "HIGH", source current, pulse ≤ 5 s	OUT1,2,3,4		0.4	A
		OUT0/Brake		3	
	Logic "LOW", means High-Z				mA
Minimum pulse width		2			µs
ESD protection	Human body model	±15			kV

Mode compliance		NPN 24V			
Default state	Not supplied (+V_{LOG} floating or to GND)	High-Z (floating)			
	Normal operation	High-Z			
Output voltage	Logic "LOW"; output current = 0.3A		0.2	0.8	V
	Logic "HIGH"; output current = 0, no load	open-collector			
	Logic "HIGH", external load to +V_{LOG}		V_{LOG}		
	Absolute maximum, continuous	-0.3		V_{LOG}+0.3	
	Absolute maximum, surge (duration ≤ 1s) †	-0.5		V_{LOG}+0.5	
Output current	Logic "LOW", sink current, continuous	OUT1,2,3,4		0.3	A
		OUT0/Brake		2	
	Logic "LOW", sink current, pulse ≤ 5 s	OUT1,2,3,4		0.5	A
		OUT0/Brake		3	
	Logic "HIGH", means High-Z				mA
Minimum pulse width		2			µs
ESD protection	Human body model	±15			kV

Brake output (OUT0/Brake)			Min.	Typ.	Max.	Units
Out0/Brake: solenoid driver, 2A.						
Default state	Not supplied (+V_{LOG} floating or to GND)		High-Z (floating)			
	Immediately after power-up	Brake-	High-Z (floating)			
	Normal operation	Brake-	High-Z (floating)			
Output voltage	Logic "LOW" (Brake-)				0.2	V
	Logic "HIGH"; load present			+V_{LOG}		
	Logic "HIGH", no load present			+5		
	Absolute maximum, continuous		-0.5		+V_{LOG} +0.3	
Output current	Logic "LOW", sink current, continuous, Brake-				3	A
	Logic "HIGH", leakage current; external load to +V_{LOG}; V_{OUT} = V_{LOG} max = 55V				0.2	mA

Digital Hall Inputs (Hall1+, Hall1-, Hall2+, Hall2-, Hall3+, Hall3-)[1]			Min.	Typ.	Max.	Units
Mode compliance			TTL / CMOS / Open-collector			
Default state	Input floating (Wiring disconnected)		Logic HIGH			
Input voltage	Logic "LOW"			0	0.8	V
	Logic "HIGH"		2	5		
	Floating voltage (Not connected)	H1+, H2+, H3+		4.4		
		H1-, H2-, H3-		1.8		
	Absolute maximum, surge (duration ≤ 1s) †		-10		+15	
Input current	Logic "LOW"; Pull to GND				1.2	mA
	Logic "HIGH"; Internal 4.7KΩ pull-up to +5		0	0	0	
Minimum pulse width			2			µs

Differential mode compliance	RS422 compliance		TIA/EIA-422-A			
Input voltage	Hysteresis		±0.06	±0.1	±0.2	V
	Differential mode		-14		+14	
	Common-mode range (A+ to GND, etc.)		-11		+14	
Input impedance, differential				120		Ω
Input frequency	Differential mode		0		10	MHz
Minimum pulse width	Differential mode		50			ns
ESD protection	Human body model		±5			kV

Encoder #1 and #2 Inputs (A1+, A1-, B1+, B1-, Z1+, Z1-, A2+, A2-, B2+, B2-, Z2+, Z2-)[2]		Min.	Typ.	Max.	Units
Differential mode compliance	For full RS422 compliance, see [1]	TIA/EIA-422-A			
Input voltage	Hysteresis	±0.06	±0.1	±0.2	V
	Differential mode	-14		+14	
	Common-mode range (A+ to GND, etc.)	-11		+14	
Input impedance, differential	A1+/A1-, B1+/B1-, Z1+/Z1-, A2+/A2-, B2+/B2-, Z2+/Z2-		120		Ω
Input frequency	Differential mode	0		10	MHz
Minimum pulse width	Differential mode	50			ns
Analog 0…5V Inputs (REF)		**Min.**	**Typ.**	**Max.**	**Units**
Input voltage	Operational range	0		5	V
	Absolute maximum values, continuous	-12		+18	
	Absolute maximum, surge (duration ≤ 1s) †			±36	
Input impedance	To GND		18		kΩ
Resolution			12		bits
Integral linearity				±2	bits
Offset error			±2	±10	bits
Gain error			±1%	±3%	% FS[3]
Bandwidth (-3Db)	Software selectable	0		1	kHz
ESD protection	Human body model	±5			kV

[1] Differential input pins have internal 120Ω termination resistors connected across when SW1 pins 1,2,3 are ON

[2] All differential input pins have internal 120Ω termination resistors connected across

[3] "FS" stands for "Full Scale"

Safe Torque OFF (STO1+; STO1-; STO2+; STO2-)		Min.	Typ.	Max.	Units
Safety function	According to EN61800-5-2	STO (Safe Torque OFF)			
EN 61800-5-1/ -2 and EN 61508-5-3/ -4 Classification	Safety Integrity Level	safety integrity level 3 (SIL3)			
	PFHd (Probability of Failures per Hour - dangerous)	$8*10^{-10}$	$hour^{-1}$ (0.8 FIT)		
EN13849-1 Classification	Performance Level	Cat3/PLe			
	MTTFd (meantime to dangerous failure)	377	years		
Mode compliance		PNP			
Default state	Input floating (wiring disconnected)	Logic LOW			
Input voltage	Logic "LOW" (PWM operation disabled)	-20		5.6	V
	Logic "HIGH" (PWM operation enabled)	18		36	
	Absolute maximum, continuous	-20		+40	
Input current	Logic "LOW"; pulled to GND		0		mA
	Logic "HIGH", pulled to +Vlog		5	10	
Diagnosis Pulse duration	Ignored high-low-high			5	ms
	Accepted pulse			20	Hz
PWM operation delay	From Enabled low-high transition to PWM operation enabled			30	ms
ESD protection	Human body model	±2			kV

CAN-Bus		Min.	Typ.	Max.	Units
Compliance		ISO11898, CiA-301v4.2, CiA 305 v2.2.13, 402v3.0			
Bit rate	Software selectable	125		1000	Kbps
Bus length	1Mbps			25	m
	500Kbps			100	
	≤ 250Kbps			250	
Resistor	Between CAN-Hi, CAN-Lo	none on-board			
Node addressing	Hardware: by SW1 switch	1-15 & 255			TMLCAN
		1-15 & 255(LSS inactive)			CANopen
	Software	1 ÷ 127 (CANopen); 1- 255 (TMLCAN)			
Voltage, CAN-Hi or CAN-Lo to GND		-26		26	V
ESD protection	Human body model	±15			kV
Supply Output (+5V)		**Min.**	**Typ.**	**Max.**	**Units**
Output voltage	Current sourced = 250mA	4.8	5	5.2	V
Output current		600	650		mA
Short-circuit		Protected			
Over-voltage		NOT protected			
ESD protection	Human body model	±1			kV
Conformity		**Min.**	**Typ.**	**Max.**	**Units**
EU Declaration	Pending	2014/30/EU (EMC), 2014/35/EU (LVD), 2011/65/EU (RoHS), 1907/2006/EC (REACH), 93/68/EEC (CE Marking Directive), EC 428/2009 (non dual-use item, output frequency limited to 590Hz)			

† Stresses beyond values listed under "absolute maximum ratings" may cause permanent damage to the device. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.