TMCM-2611-AGV Hardware Manual

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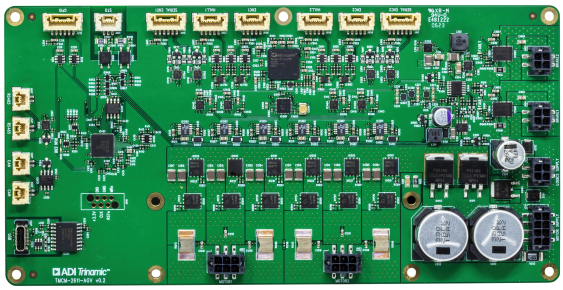
The TMCM-2611-AGV is a dual axis servo drive platform for 3-phase BLDC motors running with up to 14A_{RMS} at +48V. It offers RS485, CAN, and USB interfaces with TMCL™ protocol for communication. TMCM-2611-AGV supports various positions feedback options: incremental quadrature encoder and digital hall sensor.



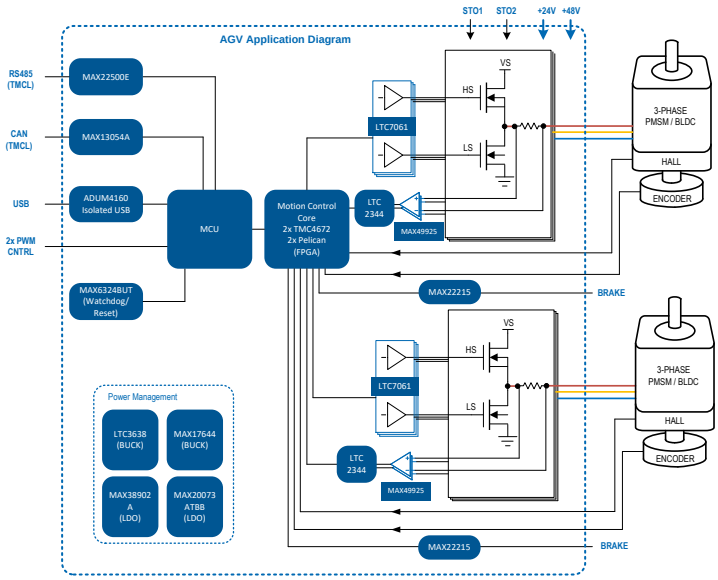
Features

- Servo Drive for BLDC Motors
- +24V System Supply
- +48V Motor Supply
- Up to 14A_{RMS} Phase Current
- RS485, CAN and USB Interfaces
- Incremental Quadrature Encoder (ABN) Interfaces
- Digital Hall Sensor Interfaces
- STO Torque-Off Inputs (Not Certified)
- Motor Brakes

Applications

- Robotics
- Laboratory Automation
- Manufacturing
- Factory Automation
- Servo Drives
- Industrial Motor Drives

Simplified Block Diagram



ANALOG DEVICES
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Contents

1 Features

The TMCM-2611-AGV is a dual axis servo drive platform for 3-phase BLDC motors running with up to 14A_{RMS} at +48V. It offers RS485, CAN, and USB interfaces with TMCL protocol for communication. TMCM-2611-AGV supports various positions feedback options: incremental quadrature encoder and digital hall sensor.

Controller and Driver

- System supply voltage: +24V DC nominal
- Motor supply voltage: +48V DC nominal
- Motor current: up to 10A_{RMS} continuous, 14A_{RMS} short time peak[1]
- Field oriented control (FOC) in hardware with up to 100kHz PWM and current control loop
- Support for BLDC motors
- Temperature rating: -30 °C to +60 °C

Position Feedback

- Incremental quadrature encoder (ABN)
- Digital hall sensor
- +5V DC supply for external sensors

I/O and Communication Interfaces

- RS485 interface (in and out) with on-board RS485 transceiver
- CAN interface (in and out) with on-board CAN transceiver
- Isolated USB interface
- Motor brake output
- STO torque-off inputs (not certified)
- Digital input

Mechanical data

- Dimensions: 200mm x 100mm
- Weight: 117g (without mating connectors and cables)
- 7x M3 mounting holes
- 2x M3 mounting holes for heatsink

Software Options

- TMCL™ remote (direct mode) and standalone operation (memory for up to 1024 TMCL commands), fully supported by TMCL-IDE (PC based integrated development environment). Further information given in the TMCM-2611-AGV TMCL firmware manual.

[1] This is the maximum current rating. This is not for continuous operation but depends on motor type, duty cycle, ambient temperature, and active/passive cooling measures.

2 Order Codes

Order Code	Description	Size
TMCM-2611-AGV	Dual axis servo drive module, 10A, +24V/+48V supply, with TMCL firmware	200mm x 100mm

Table 1: TMCM-2611-AGV Order Codes

3 Connectors and Signals

The broad set of connectors on the TMCM-2611-AGV offers high flexibility for using the module in different applications.

Supply connectors:

- System supply
- Motor supply

Motor and brake connectors (per axis):

- Motor
- Incremental quadrature encoder
- Hall sensor
- Brake output

Communication connectors:

- RS485 (in and out)
- CAN (in and out)
- USB-C

I/O connectors:

- STO
- GPIO

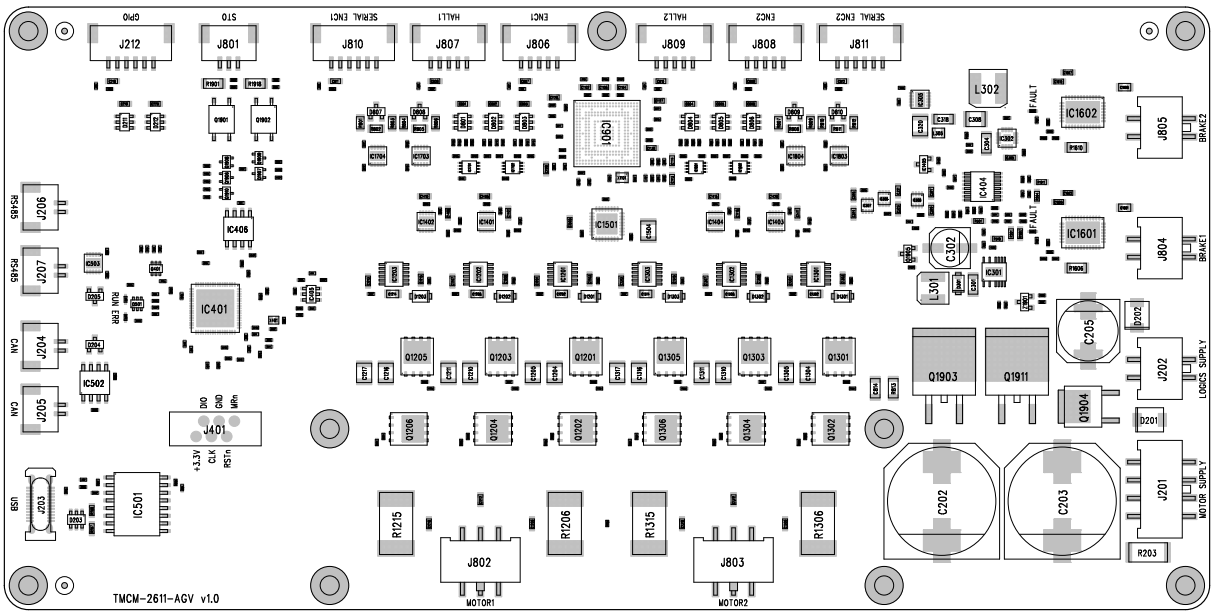

Figure 1: Location of the Connectors on the Edge of the Board

NOTE

Start with power supply OFF and do not connect or disconnect motor during operation! Motor cable and motor inductance might lead to voltage spikes when the motor is (dis)connected while energized. These voltage spikes might exceed voltage limits of the driver MOSFETs and might permanently damage them. Therefore, always switch off/disconnect power supply or at least disable driver stage before connecting/disconnecting motor.

NOTE

Take care of polarity. Wrong polarity can destroy the board!

Connector types and mating connectors		
Connector	**Connector type on-board**	**Mating connector type**
System supply	Molex 043045-0415 (2x2-pin, 3mm pitch)	Housing: Molex 043025-0408 Contacts: Molex 043030-0001 Wire gauge: AWG 20-24
Motor Supply	Molex 043045-0815 (2x4-pin, 3mm pitch)	Housing: Molex 043025-0808 Contacts: Molex 043030-0001 Wire gauge: AWG 20-24
Motor	Molex 043045-0615 (2x3-pin, 3mm pitch)	Housing: Molex 043025-0608 Contacts: Molex 043030-0001 Wire gauge: AWG 20-24
Brake	Molex 043045-0415 (2x2-pin, 3mm pitch)	Housing: Molex 043025-0408 Contacts: Molex 043030-0001 Wire gauge: AWG 20-24
Incremental encoder	JST BM05B-ZESS-TBT (5-pin, 1.5mm pitch)	Housing: JST ZER-05V-S Contacts: JST SZE-002T-P0.3 Wire gauge: AWG 24-28
Hall sensor	JST BM05B-ZESS-TBT (5-pin, 1.5mm pitch)	Housing: JST ZER-05V-S Contacts: JST SZE-002T-P0.3 Wire gauge: AWG 24-28
Serial encoder	JST BM06B-ZESS-TBT (6-pin, 1.5mm pitch)	Housing: JST ZER-06V-S Contacts: JST SZE-002T-P0.3 Wire gauge: AWG 24-28
STO	JST BM03B-ZESS-TBT (3-pin, 1.5mm pitch)	Housing: JST ZER-03V-S Contacts: JST SZE-002T-P0.3 Wire gauge: AWG 24-28
GPIO	JST BM06B-ZESS-TBT (6-pin, 1.5mm pitch)	Housing: JST ZER-06V-S Contacts: JST SZE-002T-P0.3 Wire gauge: AWG 24-28
RS485 and CAN	JST BM02B-ZESS-TBT (2-pin, 1.5mm pitch)	Housing: JST ZER-02V-S Contacts: JST SZE-002T-P0.3 Wire gauge: AWG 24-28
USB	JAE DX07S024WJ3R400	USB-C

Table 2: Connector Types and Mating Connectors

3.1 Examples for Pin Numbering

The TMCM-2611-AGV uses two types of connectors. Figure 2 and Figure 3 show those as an example. Different sizes of those plugs have Pin 1 at the same position.

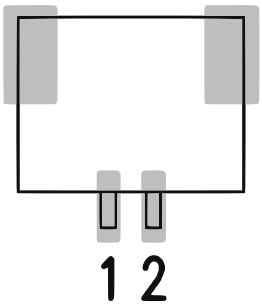

Figure 2: Pin Number Example for RS485 Connector. Other Similar.

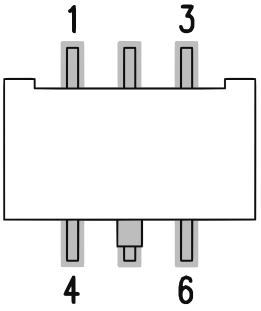

Figure 3: Pin Number Example for Motor Connector. Other Similar.

3.2 System Logic Supply Connector

Terminal	Signal	Description
1 to 2	+24V	System supply input
3 to 4	GND	Signal and supply ground

Table 3: System Supply Connector Pinout

3.3 Motor Supply Connector

NOTE **Beware that the used cables fit the required continuous current rating in the application.**

NOTE **Depending on the application, make sure to add sufficient capacitors to the driver input to stabilize driver supply.**
Low ESR electrolyte caps are recommended, especially for higher current applications. See section 4.1 for more information on this.

Terminal	Signal	Description
1 to 4	+48V	Motor supply input
5 to 8	GND	Signal and supply ground

Table 4: Motor Supply Connector Pinout

3.4 Motor Connectors

Terminal	Signal	Description
1, 4	W	BLDC motor phase W
2, 5	V	BLDC motor phase V
3, 6	U	BLDC motor phase U

Table 5: Motor Connector Pinout

3.5 Brake Output Connectors

Terminal	Signal	Description
1 to 2	BRAKE+	Positive terminal of the brake
3 to 4	BRAKE-	Negative terminal of the brake

Table 6: Brake Output Connector Pinout

3.6 Incremental Encoder Connectors

Terminal	Signal	Description
1	+5V	+5V supply output for external sensors
2	GND	Signal and supply ground
3	ENC_A	Digital incremental quadrature encoder, A channel, +5V level
4	ENC_B	Digital incremental quadrature encoder, B channel, +5V level
5	ENC_N	Digital incremental quadrature encoder, N channel, +5V level

Table 7: Incremental Encoder Connector Pinout

3.7 Hall Sensor Connectors

Terminal	Signal	Description
1	+5V	+5V supply output for external sensors
2	GND	Signal and supply ground
3	HALL_U	Digital hall sensor input, U channel, +5V level
4	HALL_V	Digital hall sensor input, V channel, +5V level
5	HALL_W	Digital hall sensor input, W channel, +5V level

Table 8: Hall Sensor Connector Pinout

3.8 Serial Encoder Connectors

Not supported. For future use.

3.9 Torque-Off Connector (STO)

Terminal	Signal	Description
1	STO1n	STO1 (inverted), +24V level
2	COM	Signal return
3	STO2	STO2, +24V level

Table 9: STO Connector Pinout

3.10 Digital GPIO Connector

Terminal	Signal	Description
1	+3.3V	+3.3V supply output for external circuitry
2	GND	Signal and supply ground
3	NC	Not connected
4	NC	Not connected
5	GPI3	Digital input, +3.3V
6	GPI4	Digital input, +3.3V

Table 10: Digital GPIO Connector Pinout

3.11 RS485 Interface Connectors

Terminal	Signal	Description
1	RS485_A	RS485 interface, diff. signal (non-inverting)
2	RS485_B	RS485 interface, diff. signal (inverting)

Table 11: RS485 Interface Connector Pinout

3.12 CAN Interface Connectors

Terminal	Signal	Description
1	CAN_H	CAN interface, diff. signal (non-inverting)
2	CAN_L	CAN interface, diff. signal (inverting)

Table 12: CAN Interface Connector Pinout

4 Interface Circuits

4.1 Supply Connection and Supply Buffering

TMCM-2611-AGV includes only limited onboard capacitance. For high current applications, additional capacitors must be placed close to the module power input to stabilize power supply. In addition, a regulated power supply is highly recommended.

NOTE

It is recommended to connect electrolytic capacitors of significant size to the power supply lines close to the TMCM-2611-AGV !
Low ESR electrolyte caps are recommended.
Rule of thumb for size of electrolytic capacitor: $C = 1000\frac{\mu F}{A} \times I_{SUPPLY}$
The capacitors should be selected with regard to high ripple current rating. In addition to power stabilization (buffer) and filtering, this added capacitor also reduces any voltage spikes, which might otherwise occur from a combination of high inductance power supply wires and the ceramic capacitors. In addition, it limits slew-rate of power supply voltage at the module. The low ESR of ceramic-only filter capacitors may cause stability problems with some switching power supplies.

4.2 Brake Output

The brake output is based on a PWM controlled half bridge driver with current feedback (MAX22215). The brake output operates at the +24V system supply level and can drive up to 3A.

4.3 Feedback Interfaces

4.3.1 Incremental Encoders

The input voltage range of the incremental quadrature encoder interfaces is 0V to 5V. The inputs have an internal 4.7kΩ pull-up resistor to 5V and the input filter has a cut-off frequency of 1.6MHz.

4.3.2 Digital Hall Sensors

The input voltage range of the hall sensor interface is 0V to 5V. The inputs have an internal 4.7kΩ pull-up resistor to 5V and the input filter has a cut-off frequency of 34kHz.

4.4 Torque-Off Interface (STO)

The STO interface has two opto-coupled inputs: STO1 (inverted) and STO2 (non-inverted). The signals have a 4.7kΩ resistor in series and 470Ω pull-down resistor to COM.

The STO input signals apply two independent methods for disconnecting the motor from torque-generating power:

- A low input level on STO1 cuts off the motor supply.
- A high input level on STO2 cuts off the driver supply.

NOTE

This torque-off interface and its circuit offers functionality known by safe torque off (STO).
Anyway, the circuit is not certified according to functional safety!

5 LED Status Indicators

The TMCM-2611-AGV has two LED status indicators for MCU status.
They are located next to the RS485 and CAN connectors on the left side of the board.

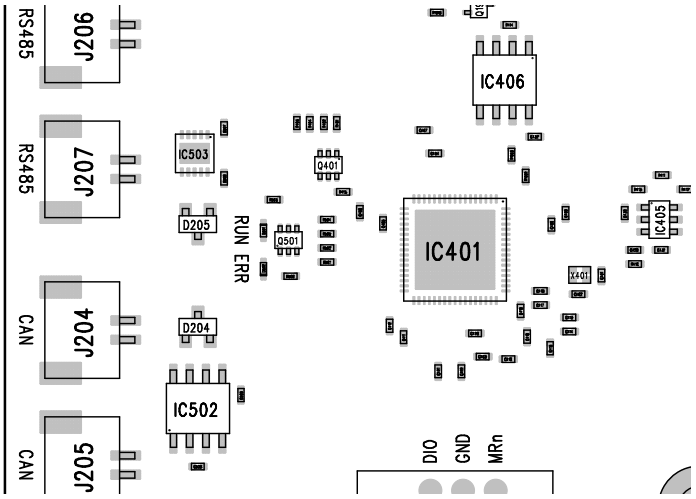

Figure 4: Location of the LEDs

LED	Description	Color
RUN	MCU status	Green
ERR	MCU error	Red

Table 13: LED Status Indicators Description

6 Communication

The following sections give some guidelines and best practices when setting up the communication bus systems supported by TMCM-2611-AGV.

6.1 RS485

For remote control and communication with a host system, the TMCM-2611-AGV provides a RS485 bus interface. There are two connectors (in and out) to simplify the cabling for systems with larger number of nodes.

For proper operation, consider the following items when setting up an RS485 network.

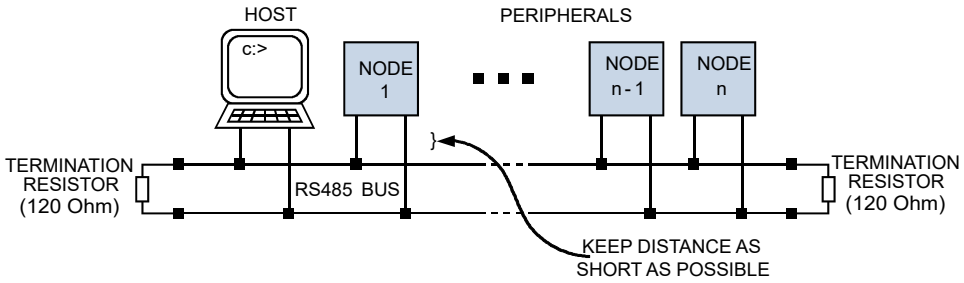

Figure 5: RS485 Bus Structure with Termination Resistors

1. *BUS STRUCTURE:*
   The network topology should follow a bus structure as closely as possible. That is, the connection between each node and the bus itself should be as short as possible. Basically, it should be short compared to the length of the bus. Figure 5 shows this.

2. *BUS TERMINATION:*
   For longer buses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-2611-AGV has no internal termination resistor. Therefore, 120Ω termination resistors at both ends of the bus have to be added externally.

3. *NUMBER OF NODES:*
   The RS485 electrical interface standard (EIA-485) allows up to 32 nodes to be connected to a single bus. *Note: Usually, reliable communication with the maximum number of nodes connected to one bus and maximum supported communication speed cannot be expected at the same time. Instead, a compromise must be found between bus cable length, communication speed, and number of nodes.*

4. *COMMUNICATION SPEED:*
   The maximum RS485 communication speed supported by the TMCM-2611-AGV hardware is 12.5Mbps. Factory default is 9.6kbps. Refer to the separate TMCM-2611-AGV TMCL firmware manual for information regarding other possible communication speeds.

5. *NO FLOATING BUS LINES:*
   Avoid floating bus lines while neither the host/master nor one of the slaves along the bus line is transmitting data (all bus nodes switched to receive mode). Floating bus lines may lead to communication errors. To ensure valid signals on the bus, it is recommended to use a resistor network connecting both bus lines to well defined logic levels.

   There are two options that can be recommended: Add resistor (bias) network on one side of the bus, only (120Ω termination resistor still at both ends):

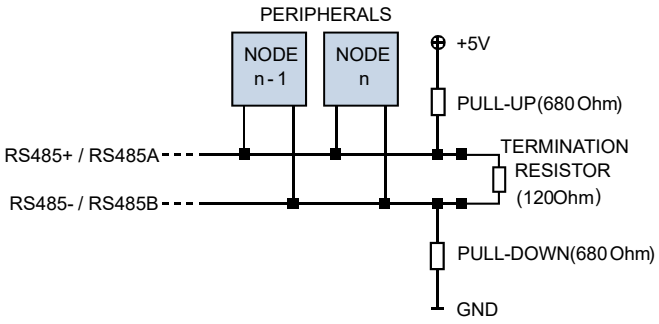

Figure 6: RS485 Bus Lines with Resistor (Bias) Network on One Side Only

Or add resistor network at both ends of the bus:

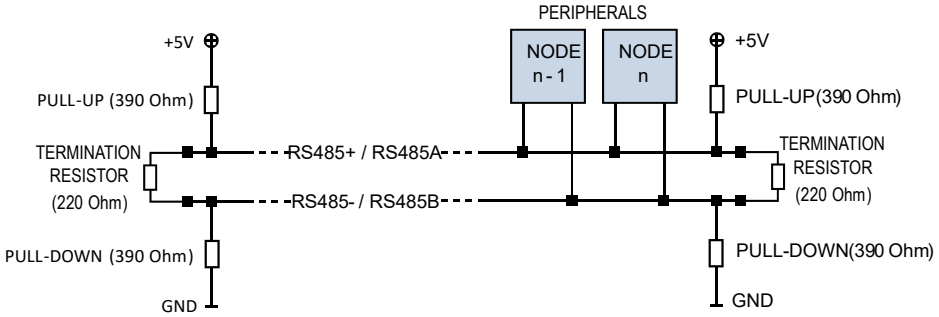

Figure 7: RS485 Bus Lines with Resistor (Bias) Network on Both Sides

6.2 CAN

For remote control and communication with a host system, the TMCM-2611-AGV provides a CAN bus interface. There are two connectors (in and out) to simplify the cabling for systems with larger number of nodes.

For proper operation, consider the following items when setting up a CAN network:

1. *BUS STRUCTURE:*
   The network topology should follow a bus structure as closely as possible. That is, the connection between each node and the bus itself should be as short as possible. Basically, it should be short compared to the length of the bus.

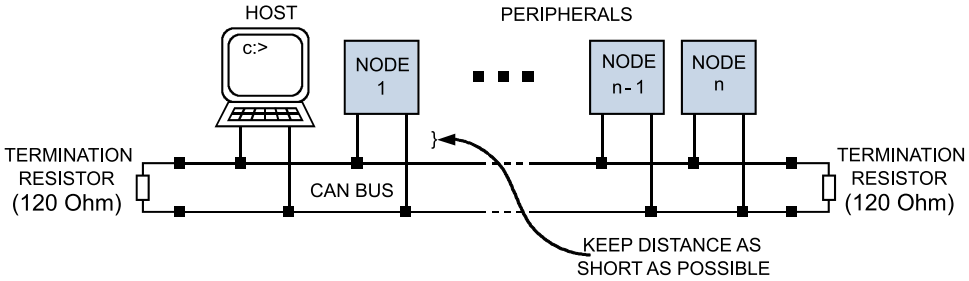

Figure 8: CAN Bus Structure with Termination Resistors

2. *BUS TERMINATION:*
   For longer buses and/or multiple nodes connected to the bus and/or high communication speeds, the bus should be properly terminated at both ends. The TMCM-2611-AGV does not integrate any termination resistor. Therefore, 120Ω termination resistors at both ends of the bus have to be added externally.

3. *NUMBER OF NODES:*
   Practically achievable number of nodes per CAN bus highly depend on bus length (longer bus -> less nodes) and communication speed (higher speed -> less nodes).

7 Operational Ratings and Characteristics

7.1 Absolute Maximum Ratings

Parameter	Min	Max	Unit
System supply voltage		28	V
Motor supply voltage		72	V
Maximum motor phase current		14[1]	Arms
Sensor supply output current		0.25	A
Incremental encoder input voltage	-0.5	6.5	V
Hall sensor input voltage	-0.5	6.5	V
Serial encoder input voltage	-15	15	V
STO input voltage	-6	35	V
RS485 input voltage	-15	15	V
CAN input voltage	-26	26	V
Ambient temperature	-40	+85[2]	°C

Table 14: Absolute Maximum Ratings

⚠ DANGER While using the module with $14A_{RMS}$, the power stage area reaches up to 120 °C without sufficient cooling. **Do not touch!**

NOTE Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

[1] This is the maximum current rating. This is not for continuous operation but depends on motor type, duty cycle, ambient temperature, and active/passive cooling measures.

[2] Working at high environmental temperatures may require additional cooling measures depending on duty cycle and maximum current/power draw.

7.2 Operational Ratings

Ambient temperature 25 °C, if not stated otherwise.

7.2.1 System Supply

Parameter	Symbol	Min	Typ	Max	Unit
System supply voltage	$+VS$	20	24	28	V

Table 15: System Supply Operational Ratings

7.2.2 Motor Supply

Parameter	Symbol	Min	Typ	Max	Unit
Motor supply voltage	$+VM$	14	48	72	V

Table 16: Motor Supply Operational Ratings

7.2.3 Motor

Parameter	Symbol	Min	Typ	Max	Unit
Continuous motor phase current	I_{phase}			10	Arms

Table 17: Motor Operational Ratings

7.2.4 Brake Output

Parameter	Symbol	Min	Typ	Max	Unit
Output current	I_{OUT}			3	A
Output ON-resistance	R_{ON}		50		mΩ

Table 18: Brake Output Operational Ratings

7.2.5 STO

Parameter	Symbol	Min	Typ	Max	Unit
Input voltage range	V_{IN}	0		28	V
Cut-off frequency	f_{cutoff}		0.34		kHz

Table 19: STO Operational Ratings

7.2.6 Incremental Encoder

Parameter	Symbol	Min	Typ	Max	Unit
+5V sensor supply output current	I_{+5V}			0.1	A
Input voltage range	V_{IN}	0		5.5	V
Input high threshold voltage	V_{TH}		1.8		V
Input low threshold voltage	V_{TL}		1.1		V
Cut-off frequency	f_{cutoff}		1.6		MHz

Table 20: Incremental Encoder Operational Ratings

7.2.7 Hall Sensor

Parameter	Symbol	Min	Typ	Max	Unit
+5V sensor supply output current	I_{+5V}			0.1	A
Input voltage range	V_{IN}	0		5.5	V
Input high threshold voltage	V_{TH}		1.8		V
Input low threshold voltage	V_{TL}		1.1		V
Cut-off frequency	f_{cutoff}		34		kHz

Table 21: Hall Sensor Operational Ratings

7.2.8 RS485

Parameter	Symbol	Min	Typ	Max	Unit
Common mode input voltage range	V_{IC}	-15		15	V
Differential input high threshold voltage	V_{TH}	50		200	mV
Differential input low threshold voltage	V_{TL}	-200		-50	mV
Common mode output voltage	V_{OC}		2.5	3	V
Differential output voltage	V_{OD}	1.5			V
Data rate	DR			12.5[1]	Mbps

Table 22: RS485 Operational Ratings

[1] This is the electrical value. Note that the firmware speed is lower.

7.2.9 CAN

Parameter	Symbol	Min	Typ	Max	Unit
Common mode input voltage range	V_{IC}	-25		25	V
Differential input dominant threshold voltage	V_{TH}			0.9	V
Differential input recessive threshold voltage	V_{TL}	0.5			V
Common mode output voltage	V_{OC}	2		3	V
Differential output voltage	V_{OD}	1.5		3	V
Data rate	DR			2[1]	Mbps

Table 23: CAN Operational Ratings

7.2.10 USB

Parameter	Symbol	Min	Typ	Max	Unit
Isolation	V_{ISO}	5			kV_{RMS}
Data rate	DR		1.5		Mbps

Table 24: USB Operational Ratings

7.3 Other Requirements

Specifications	Description or Value
Temperature	-30 °C to +60 °C Use appropriate cooling depending on the use case, required power output, and environmental temperature.
Environment	Avoid dust, water, oil mist and corrosive gases, no condensation, no frosting.

Table 25: Other Requirements and Characteristics

[1] This is the electrical value. Note that the firmware speed is lower.

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10 Supplemental Directives

10.1 Producer Information

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10.7 Collateral Documents & Tools

This product documentation is related and/or associated with additional tool kits, firmware and other items, as provided on the product page at: www.analog.com.

11 Revision History

11.1 Hardware Revision

Version	Date	Description
V1.0	07/23	Release version

Table 26: Hardware Revision

11.2 Document Revision

Version	Date	Description
0	12/23	Initial release

Table 27: Document Revision