

3-Axis Stepper Motor Controller/Driver Module

FEATURES

- ▶ 3-Axis Stepper Motor Controller/Driver
- ▶ 24V (10V–30V) Supply Voltage Range
- ▶ 3x 1.5A_{RMS} (2A_{RMS} Peak) Motor Current
- ▶ Eight-Point Hardware Ramp Generator
- ▶ StealthChop™/SpreadCycle™
- ▶ REFL/REFR Reference Switch Inputs per Motor Axis
- ▶ A/B/N Encoder Input per Motor Axis
- ▶ 4x DIGITAL_IN/OUT, 24V Push-Pull or High-Side
- ▶ 2 ANALOG_IN, 0V–10V
- ▶ RS485/CAN/USB Interfaces
- ▶ 85mm x 55mm (Credit-Card Size)
- ▶ Automatic Board Address Assignment at Power-Up (Optional)
- ▶ TMCL, CANopen

APPLICATIONS

- ▶ Industrial Automation
- ▶ Laboratory Automation
- ▶ Medical Devices

GENERAL DESCRIPTION

The TMCM-3216 is a compact, 3-axis bipolar stepper motor controller and standalone driver board. It supports up to three bipolar stepper motors with up to 2A_{RMS} motor coil current and offers single-supply operation with typical 24V_{DC} (10V–30V range).

There are separate reference/stop switches and incremental A/B/N encoder inputs per motor axis. In addition, the module offers four programmable digital inputs and outputs that are configurable as push-pull or high-side outputs. Two analog inputs support 0V–10V signals.

A USB interface is available for configuration and updates. The RS485 and CAN bus interfaces can be used for in-system communication and daisy-chaining boards to simplify wiring through bus connectors at each end of the board.

SIMPLIFIED APPLICATION DIAGRAM

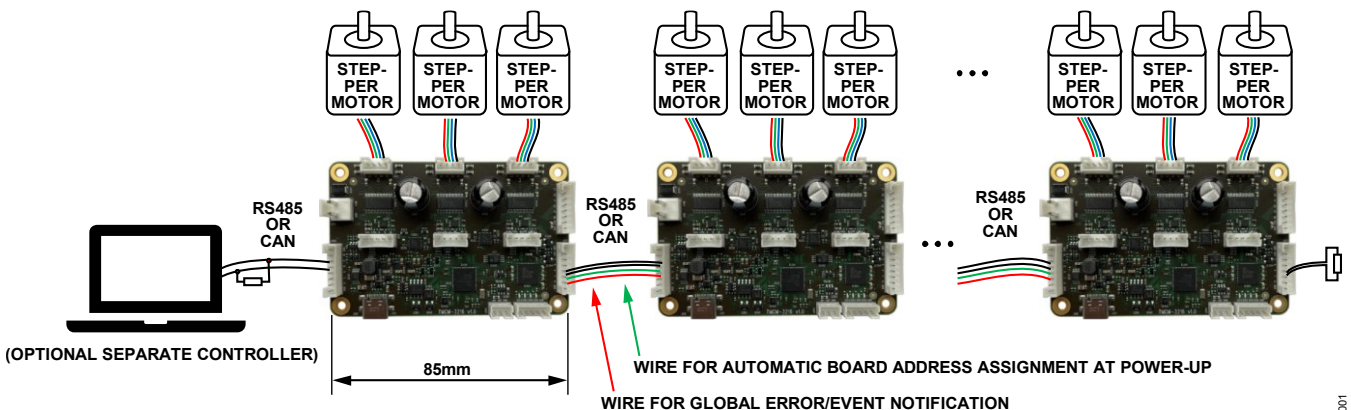


Figure 1. Multiaxis Application Example

REVISION HISTORY

12/2024 - Rev. 0: Release for Market Intro


SPECIFICATIONS

Table 1. Electrical Characteristics

PARAMETER	SYMBOL	CONDITIONS	COMMENTS	MIN	TYP	MAX	UNITS
Supply Input Voltage	V_{SUPPLY}			10	24	30	V
Supply Input Current	I_{SUPPLY}				$\ll 3 \times I_{MOTOR}$	$3 \times I_{MOTOR_FS} + \text{Digital I/O}$	A
Motor Current (RMS)	I_{MOTOR}				1.5	2	A_{RMS}
Motor Coil Current Sine Wave Peak	I_{MOTOR_FS}					2.8	A
Environmental Temperature at Rated Motor Current (3x 1.5A RMS), No Forced Cooling	T_{ENV}			-40		+40	°C
Output Voltage for +5V	V_{+5V}			4.5		5.5	V
Output Current for +5V	I_{+5V}		All +5V output pins together			400	mA
Reference Switch REFL/R Input Voltage	$V_{REFL/R}$		Type 1/3 Digital Input			30	V
Low-Level Reference Switch REFL/R Input Voltage	V_{REFL/R_L}		Type 1/3 Digital Input			8	V
High-Level Reference Switch REFL/R Input Voltage	V_{REFL/R_H}		Type 1/3 Digital Input	10			V
A/B/N Encoder Signal Input Voltage	V_{ENC}		Internal 47k Ω pull-up resistor to +5V	0		+5.5	V
Low-Level A/B/N Encoder Signal Input Voltage	V_{ENC_L}					0.8	V
High-Level A/B/N Encoder Signal Input Voltage	V_{ENC_H}			2			V
Digital I/O Output Current for High-Side Switch Configuration (HS)	$I_{DIGITAL_HS}$				175		mA
Digital I/O Output Current for Push-Pull Configuration (PP)	$I_{DIGITAL_PP}$				200		mA
Digital I/O Input Voltage Range for Input Configuration	$V_{DIGITAL}$		Type 1/3 Digital Input			V_{SUPPLY}	V

PARAMETER	SYMBOL	CONDITIONS	COMMENTS	MIN	TYP	MAX	UNITS
Low-Level Digital I/O Input Voltage for Input Configuration	$V_{\text{DIGITAL_L}}$		Type 1/3 Digital Input			6.7	V
High-Level Digital I/O Input Voltage for Input Configuration	$V_{\text{DIGITAL_H}}$		Type 1/3 Digital Input	8			V
Analog Input Voltage Range	V_{ANALOG}				0–10	30	V
EVENT Output Voltage Range	V_{EVENT}		Internal 47k Ω pull-up resistor to +5V		0–5	30	V
Event Output Sink Current	I_{EVENT}					20	mA
ADDR_OUT Output Voltage Range	$V_{\text{ADDR_OUT}}$		Internal 47k Ω pull-up resistor to +5V		0–5	30	V
ADDR_IN Input Voltage Range	$V_{\text{ADDR_IN}}$				0–5	30	V

Table 2. Thermal Characteristics

Test Setup	Lay the TMCM-3216 flat on the test bench. Natural air convection/no forced cooling at room temperature (25°C). Three connected stepper motors move slowly throughout the test.
Motor Current	3x 1.5A _{RMS} /2A peak
Supply Voltage	24V
Thermal Image Taken after a 30-Minute Test Period	
Hot Spot	104°C is the maximum temperature at a 25°C environmental temperature.
Test result	The board reaches its maximum temperature at the driver stage for motor axis 1. The maximum temperature is still well below the absolute maximum temperature specified for the driver ICs.

ABSOLUTE MAXIMUM RATINGS

$T_A = 25^\circ\text{C}$, unless otherwise specified.

Table 3. Absolute Maximum Ratings

PARAMETER	RATING
Supply Input Voltage	-0.3V to +33V
Reference Switch REFL/R Input Voltage	-40V to +40V
Digital I/O Input Voltage Range for Input Configuration	-1V to $V_{\text{SUPPLY}} + 0.3\text{V}$
Analog Input Voltage Range	-0.3V to +40V
EVENT Output Voltage Range	-0.3V to +36V
ADDR_OUT Output Voltage Range	-0.3V to +36V
ADDR_IN Input Voltage Range	-0.3V to +36V

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

Electrostatic Discharge (ESD)

ESD Caution



ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

Notes on Security

The TMCM-3216 comes without enclosure or additional protection. It is intended for embedded motion control—to be integrated into customer system/machine with stepper motors, I/Os, and communication links connected internally according to application requirements. The customer is responsible for protecting the TMCM-3216 sufficiently inside the system/machine against direct access by the end user.

PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

Overview

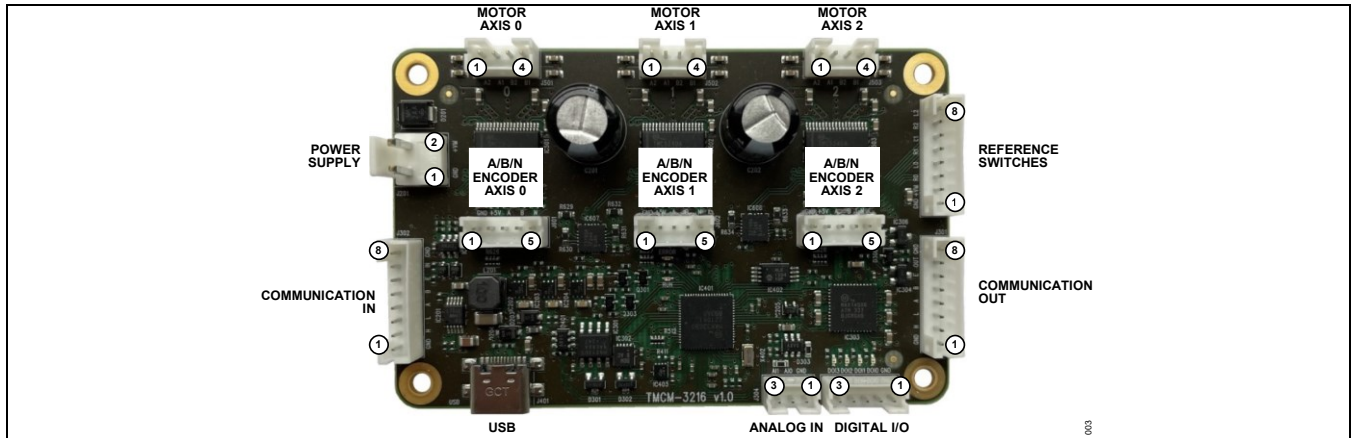


Figure 2. TMCM-3216 Connectors

Table 4. Connector Types and Mating Connectors

Connector	Connector Type	Mating Connector Type
Power Supply	JST B2P-VH (JST VH series, 2 pins, 3.96mm pitch)	Connector housing: JST VHR-2N Contacts: JST SVH-21T-P1.1 Wire: 0.83mm ² , AWG 18
Motor Axis 0-2	JST B4B-PH-K-S (JST PH series, 4 pins, 2mm pitch)	Connector housing JST: PHR-4 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
Reference Switches	JST B8B-PH-K-S (JST PH series, 8 pins, 2mm pitch)	Connector housing JST: PHR-8 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
A/B/N Encoder Axis 0-2	JST B5B-PH-K-S (JST PH series, 5 pins, 2mm pitch)	Connector housing JST: PHR-5 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
Communication In	JST B8B-PH-K-S (JST PH series, 8 pins, 2mm pitch)	Connector housing JST: PHR-8 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
Communication Out	JST B8B-PH-K-S (JST PH series, 8 pins, 2mm pitch)	Connector housing JST: PHR-8 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
Digital I/O	JST B5B-PH-K-S (JST PH series, 5 pins, 2mm pitch)	Connector housing JST: PHR-5 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
Analog In	JST B3B-PH-K-S (JST PH series, 3 pins, 2mm pitch)	Connector housing JST: PHR-3 Contacts JST: SPH-002T-P0.5S Wire: 0.22mm ² , AWG 24
USB	USB-C	USB-C

Power-Supply Connector

Table 5. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	V _{SUPPLY}	Main Supply Input		IN

Motor Axis 0-2 Connector

Table 6. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	A2	Pin 2 of Motor Coil A	V _{SUPPLY}	OUT
2	A1	Pin 1 of Motor Coil A	V _{SUPPLY}	OUT
3	B2	Pin 2 of Motor coil B	V _{SUPPLY}	OUT
4	B1	Pin 1 of Motor Coil B	V _{SUPPLY}	OUT

Reference Switches Connector

Table 7. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	V _{SUPPLY}	V _{SUPPLY} Supply Path through Output Note: Do not use this pin as a power supply input for the module.	V _{SUPPLY}	OUT
3	REFR0	Axis 0 Reference Switch Input Right (24V industrial type 1/3 digital input)	V _{SUPPLY}	IN
4	REFL0	Axis 0 Reference Switch Input Left (24V industrial type 1/3 digital input)	V _{SUPPLY}	IN
5	REFR1	Axis 1 Reference Switch Input Right (24V industrial type 1/3 digital input)	V _{SUPPLY}	IN
6	REFL1	Axis 1 Reference Switch Input Left (24V industrial type 1/3 digital input)	V _{SUPPLY}	IN
7	REFR2	Axis 2 Reference Switch Input Right (24V industrial type 1/3 digital input)	V _{SUPPLY}	IN
8	REFL2	Axis 2 Reference Switch Input Left (24V industrial type 1/3 digital input)	V _{SUPPLY}	IN

A/B/N Encoder Axis 0-2 Connector

Table 8. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	+5V	+5V Supply Output		OUT
3	ENC_A	Encoder A-Channel Input (internal 47k Ω pull-up resistor to +5V)	+5V	IN
4	ENC_B	Encoder B-Channel Input (internal 47k Ω pull-up resistor to +5V)	+5V	IN
5	ENC_N	Encoder N-Channel Input (internal 47k Ω pull-up resistor to +5V)	+5V	IN

Communication-In Connector

Table 9. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	CAN_H	CAN Interface, Differential Signaling (Noninverting) (Connected to communication-out connector/pass-through)		IN/OUT
3	CAN_L	CAN Interface, Differential Signaling (Inverting) (Connected to communication-out connector/pass-through)		IN/OUT
4	RS485_A	RS485 Interface, Differential Signaling (Noninverting) (Connected to communication-out connector/pass-through)		IN/OUT
5	RS485_B	RS485 Interface, Differential Signaling (Inverting) (Connected to communication-out connector/pass-through)		IN/OUT
6	EVENT	Event Input and Output (Open drain with an internal 47k Ω pull-up resistor to +5V; connected to communication-out connector/pass-through)	V _{SUPPLY}	IN/OUT
7	ADDR_IN	Input Signal for Automatic Board Address Assignment	V _{SUPPLY}	IN
8	GND	Common-Supply GND		

Communication-Out Connector

Table 10. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	CAN_H	CAN Interface, Differential Signaling (Noninverting) (Connected to communication-in connector/pass-through)		IN/OUT
3	CAN_L	CAN Interface, Differential Signaling (Inverting) (Connected to communication-in connector/pass-through)		IN/OUT
4	RS485_A	RS485 Interface, Differential Signaling (Noninverting) (Connected to communication-in connector/pass-through)		IN/OUT
5	RS485_B	RS485 Interface, Differential Signaling (Inverting) (Connected to communication-in connector/pass-through)		IN/OUT
6	EVENT	Event Input and Output (Open drain with an internal 47kΩ pull-up resistor to +5V; connected to communication-in connector/pass-through)	V _{SUPPLY}	IN/OUT
7	ADDR_OUT	Output Signal (Open drain with an internal 47kΩ pull-up resistor to +5V for automatic board address assignment)	V _{SUPPLY}	OUT
8	GND	Common-supply GND		

Digital I/O Connector

Table 11. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	DIO0	General-Purpose Digital Input 0/Output 0 Digital input: 24V industrial type 1/3 Digital output: High-side switch or push-pull driver	V _{SUPPLY}	IN/OUT
3	DIO1	General-Purpose Digital Input 1/Output 1 Digital input: 24V industrial type 1/3 Digital output: High-side switch or push-pull driver	V _{SUPPLY}	IN/OUT
4	DIO2	General-Purpose Digital Input 2/Output 2 Digital input: 24V industrial type 1/3 Digital output: High-side switch or push-pull driver	V _{SUPPLY}	IN/OUT
5	DIO3	General-Purpose Digital Input 3/Output 3 Digital input: 24V industrial type 1/3 Digital output: High-side switch or push-pull driver	V _{SUPPLY}	IN/OUT

Analog-In Connector

Table 12. Pin Descriptions

PIN	NAME	DESCRIPTION	REF SUPPLY	TYPE
1	GND	Common-Supply GND		
2	AIN1	General-Purpose Analog Input 1 (0V–10V)		IN
3	AIN0	General-Purpose Analog Input 0 (0V–10V)		IN

DETAILED DESCRIPTION

The TMCM-3216 is a highly-integrated, 3-axis stepper motor controller/driver module. It can be controlled through CAN, RS485, or USB serial interfaces.

The three stepper drivers support up to $2A_{RMS}$ motor current and up to 256 microsteps per full step. Select either SpreadCycle chopper algorithm for highly-dynamic motor control or StealthChop2 chopper for silent motor operation. StallGuard2 or StallGuard4 can be used for sensorless load estimation. As an alternative, an incremental A/B/N encoder for step loss/deviation detection under all operating conditions is supported for all three axes. There are separate reference/stop switch inputs for each direction and motor.

For each axis, an eight-point motion ramp generator built into the hardware is available to support independent position movements and velocity control with on-the-fly changes.

An integrated Arm® M4 microcontroller provides CAN, RS485, and USB interfaces and connects to the three integrated stepper motor controllers and drivers. It supports overall system control, initialization, initiation, and synchronization of motor movements and communication protocol handling. There are two pre-loaded firmware versions: TMCL and CANopen.

The TMCL version of TMCM-3216 comes with the PC-based software development environment TMCL-IDE for the Trinamic Motion Control Language (TMCL). Using predefined TMCL high-level commands, such as move to position, a rapid and fast development of motion control applications is guaranteed. Communication traffic is kept low since all time critical operations, such as ramp calculations, are performed on board. Full remote control of the device with feedback is possible. The firmware of the module can be updated through any of the serial interfaces.

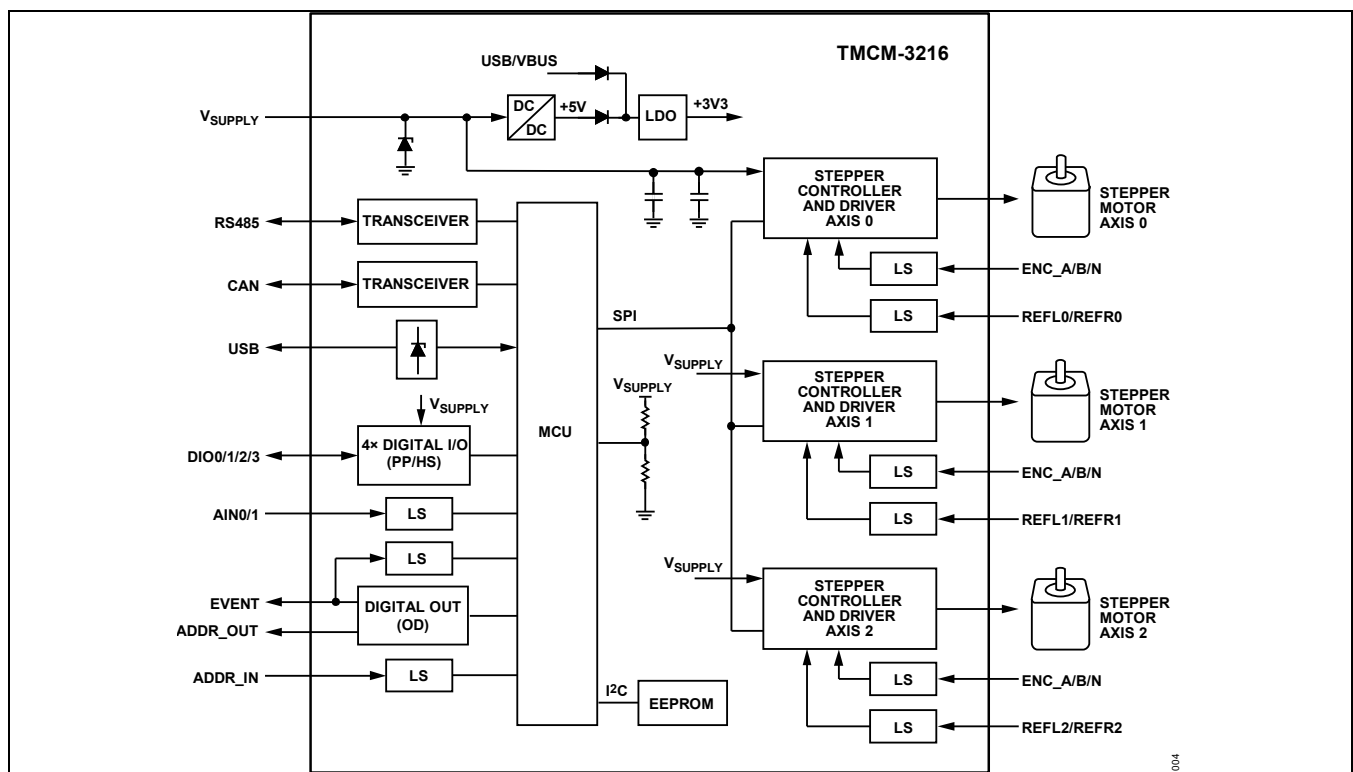


Figure 3. TMCM-3216 Block Diagram

RS485

For remote control and communication with a host system, the TMCM-3216 provides a 2-wire RS485 bus interface. For proper operation, consider the following items when setting up an RS485 network:

- **Bus Structure:** The network topology needs to follow a bus structure as closely as possible. The TMCM-3216 supports this structure by providing communication connectors at both ends of the board that pass through the RS485 differential signals with a comparatively short stub connected to the on-board RS485 transceiver.
- **Bus Termination:** For longer busses and/or multiple nodes connected to the bus and/or high communication speeds, properly terminate the bus at both ends. The TMCM-3216 does not integrate any termination resistor. Therefore, externally add 120Ω termination resistors at both ends of the bus.
- **Number of Nodes:** The RS485 electrical interface standard (EIA-485) allows up to 32 nodes to be connected to a single bus. Usually, it is not expected to get reliable communication with a high number of nodes connected to one bus and maximum supported communication speed at the same time. Instead, a compromise must be made among bus cable length, communication speed, and number of nodes.
- **Communication Speed:** Factory default is 9.6kbps.
- **No Floating Bus Lines:** Avoid floating bus lines when neither the host/controller nor one of the peripheral devices along the bus line is transmitting data (all bus nodes are switched to receive mode). Floating bus lines can 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 recommendations. The first recommendation is to add a resistor (bias) network on one side of the bus only with a 120Ω termination resistor at both ends. See Figure 4.

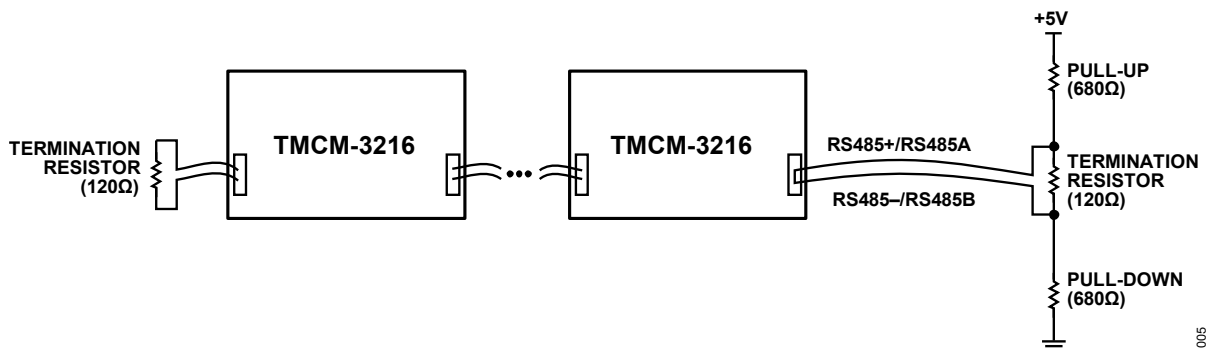


Figure 4. Bus Lines with a Resistor (Bias) Network on One Side Only

The second recommendation is to add a resistor (bias) network at both ends of the bus, which is often referred to as Profibus™ termination. See Figure 5.

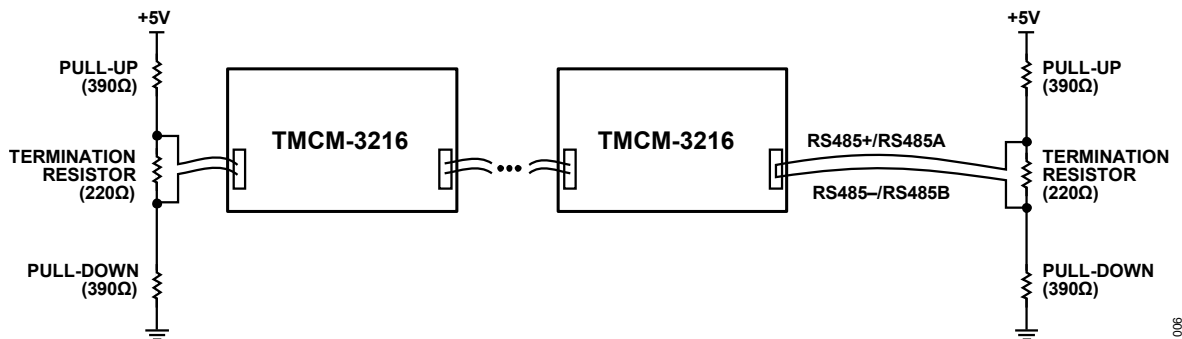


Figure 5. Bus Lines with a Resistor (Bias) Network at Both Ends

CAN

For remote control and communication with a host system, the TMCM-3216 also provides a CAN bus interface. For proper operation, consider the following items when setting up a CAN network:

- **Bus Structure:** The network topology needs to follow a bus structure as closely as possible. The TMCM-3216 supports this structure by providing communication connectors at both ends of the board that pass through the CAN differential signals with a comparatively short stub connected to the on-board CAN transceiver.
- **Bus Termination:** For longer busses and/or multiple nodes connected to the bus and/or high communication speeds, properly terminate the bus at both ends. The TMCM-3216 does not integrate any termination resistor. Therefore, add external 120Ω termination resistors at both ends of the bus.
- **Number of Nodes:** The practically achievable number of nodes per CAN bus highly depends on bus length (longer bus → less nodes) and communication speed (higher speed → less nodes).
- **Communication Speed:** Factory default is 1Mbps.

USB

For remote control and communication with a host system, the TMCM-3216 provides a USB interface (USB-C connector). As soon as a USB host is connected, the module accepts commands through USB. The TMCM-3216 supports self-powered USB operation (when an external power is supplied through the power supply connector) and USB bus-powered operation (with no external power supply through power-supply connector).

During USB bus-powered operation, only the core digital parts are operational (e.g., the microcontroller and the EEPROM). Motor movements are not possible. This mode has been implemented to enable configuration/parameter setting/readout, firmware updates, etc. simply by connecting a USB cable between the module and a host PC. No additional cabling or external devices are required in that case.

Note that the module might draw current from the USB +5V bus supply even in USB self-powered operation, depending on the voltage level of this supply.

The USB interface can be used for configuration/firmware updates, initial tests, and service. For in-system communication, it is recommended to rely on the more robust RS485 or CAN bus interfaces.

On-Board LEDs

The board offers two LEDs to indicate board status, labeled **Error** and **Run**. The LEDs function depends on the firmware version. With TMCL firmware, the green **Run** LED slowly flashes during operation, and the red **Error** LED does not illuminate. Refer to the TMCM-3216 TMCL firmware manual for additional information. When there is no valid firmware programmed into the board or during firmware update, the red and green LEDs remain illuminated.

Additionally, there are four green LEDs to indicate the status of the DIO0/1/2/3 digital inputs and outputs at the digital I/O connector. The LEDs indicate an active (high) state of the digital outputs or inputs.

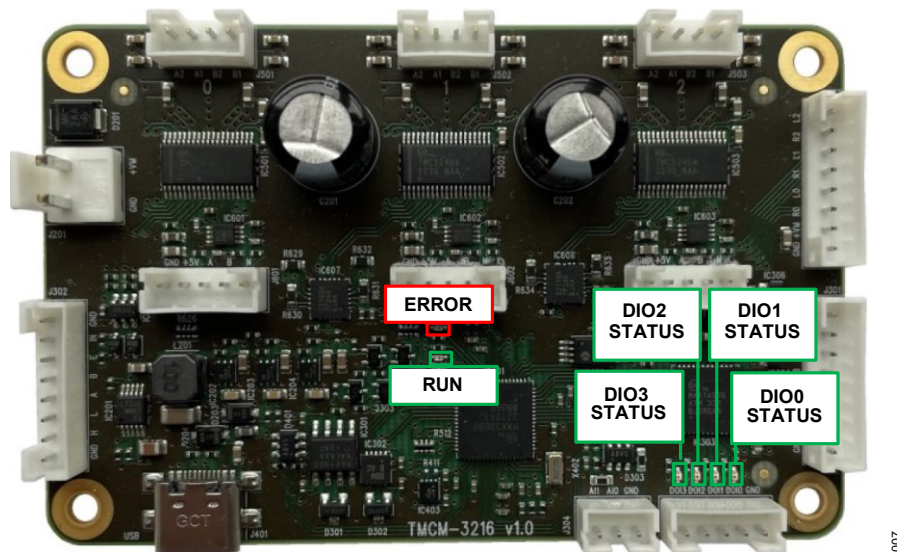


Figure 6. On-Board LEDs

Reset to Factory Defaults

It is possible to reset all the TMCM-3216 settings in the firmware to factory defaults without establishing a working communication connection. This approach may be helpful in case communication parameters of the preferred interface are accidentally set to unknown values or get lost during evaluation/prototype setup.

For this reset procedure, two test pads on the bottom side of the module must be shorted (electrically connected with each other) at power-up. Use the following procedure:

1. Switch off the power supply. **Optional:** Disconnect the USB cable, if applicable.
2. Short the pads on the bottom of the PCB. See [Figure 7](#).
3. Switch on the power supply again. **Optional:** Connect the USB cable again, if applicable.
4. Wait until the on-board red (**Error**) and green (**Run**) LEDs start flashing fast. **Note:** This may take several seconds.
5. Switch off the power supply. **Optional:** Disconnect the USB cable, if applicable.
6. Remove the short between pads.

- After switching on the power supply again (or optionally connecting the USB cable again, if applicable), all permanent settings are restored to factory defaults.

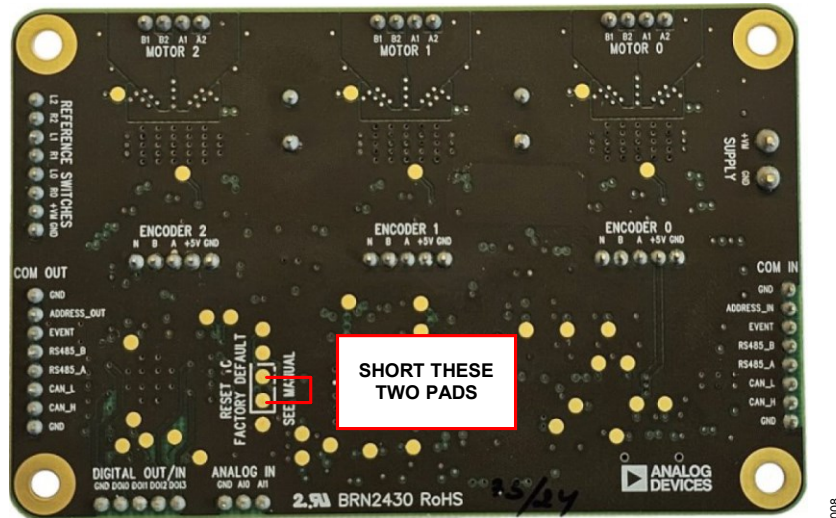


Figure 7. PCB Bottom View—Reset to Factory Defaults

OUTLINE DIMENSIONS

The board with the controller/driver electronics measures at 85mm x 55mm overall and offers four mounting holes for M3 screws (3.2mm diameter). The maximum board height without mating connectors and cable looms is approximately 15mm above the printed circuit board level.

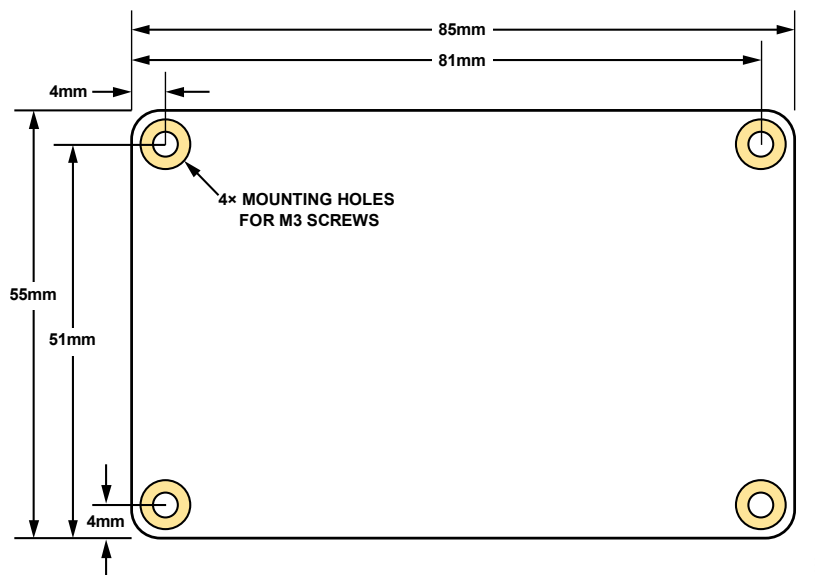


Figure 8. Board Dimensions and Position of Mounting Holes

The TMCM-3216 offers four metal-plated mounting holes. All four mounting holes are DC-coupled to a common-supply GND. To minimize distortion of signals and radiation of HF signals (i.e., to improve EMC compatibility), especially in sensitive or noisy environments, it is important to ensure a solid ground connection within the system. To further support this approach, it is recommended to connect all four mounting holes of the board and the supply-input ground to the system power-supply ground.

However, this approach might not always be an option. For example, if the metal system chassis/TMCM-3216 mounting plate is already connected to ground, a direct connection between the supply ground (secondary side) and the mains supply ground (primary side) is not desired or not an option. In this case, use plastic (e.g., nylon) spacers, distance bolts, and screws.

ORDERING GUIDE

Table 13. Ordering Guide

MODEL	DESCRIPTION	SIZE OF UNIT
TMCM-3216-TMCL	3-Axis Stepper Motor Controller Driver Module, Preprogrammed with TMCL Firmware	85mm x 55mm x 20mm
TMCM-3216-CANOPEN	3-Axis Stepper Motor Controller Driver Module, Preprogrammed with CANopen Firmware	85mm x 55mm x 20mm

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