TMCM-1290 Hardware Manual

Hardware Version V1.00 | 19-101825B, Rev 1: 04/24

The TMCM-1290 is a single axis controller and driver module for 2-phase stepper motors. It comes either with TMCL or with Modbus firmware installed and communicates through RS485 or SPI. Both allow use of the TMC5240 motion controller and motor driver. StealthChop, SpreadCycle, Stall-Guard2 , and CoolStep allow for dynamic current control and quiet, smooth, and efficient motor operation.
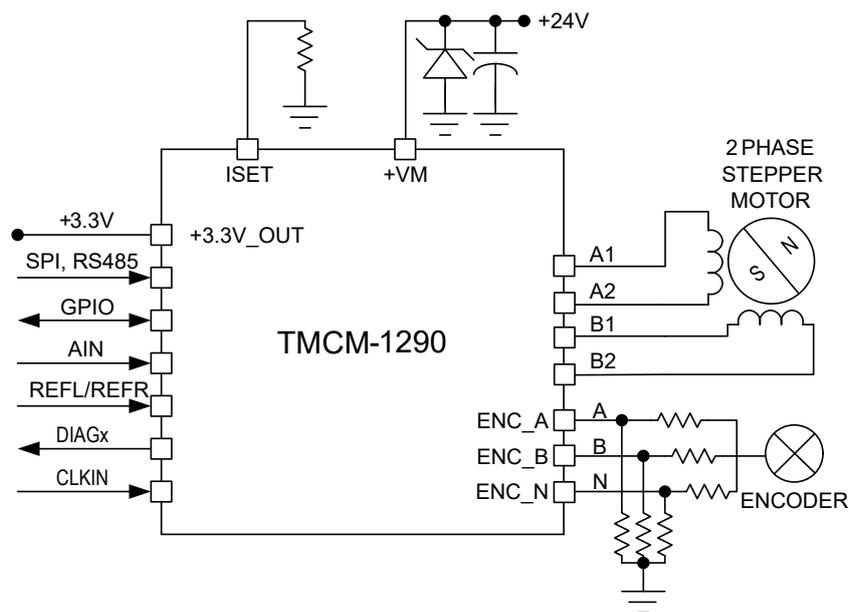

Features

- Supply Voltage +4.5 to +36V DC
- Up to 2.1A Motor RMS Current
- RS485 and SPI
- TMCL™ and Modbus Protocol Stack
- Integrated Stepper Motor Driver
- Integrated 8-Point Motion Controller
- StealthChop2 CoolStep StallGuard2 SpreadCycle Support
- ABN Incremental Encoder Interface
- Reference Switch Inputs
- Analog and Digital IO
- +3.3V Supply for Peripherals
- Compact Size (24mm x 20.5mm)

Applications

- Broad Market
- System Integrators
- Lab Automation
- Textile
- Packaging
- Life Sciences
- Semiconductor Handling
- Pumps and Motor Drives
- Multi-Axis Applications

Simplified Block Diagram

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Contents

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1 Features

The TMCM-1290 is a single axis controller and driver module for 2-phase stepper motors with state of the art feature set. It is highly integrated and is suited for decentralized applications. The module supports stepper motor coil currents of up to 2.1A$_{RMS}$ and 36V DC supply voltage. With its high energy efficiency from ADI Trinamic's CoolStep technology, cost for power consumption is kept down.

Motion Controller

- Motion profile calculation in real-time
- On-the-fly alteration of motor parameters (for example position, velocity, acceleration)
- Linear and unique EightPoint ramp in hardware
- Encoder interface and reference/stop switch inputs

Driver

- Motor current: up to 2.1A$_{RMS}$ (3A$_{peak}$, programmable in software)
- Supply voltage: +24V DC (+4.5 to +36V DC)
- Up to 256 microsteps per full step
- High-efficient operation, low power dissipation
- Dynamic current control
- Integrated protection
- StealthChop feature for quiet operation and smooth motion
- StallGuard2 feature for stall detection
- CoolStep feature for reduced power consumption and heat dissipation

Interfaces, IOs, and LEDs

- RS485 bus interface with integrated transceiver
- SPI
- ABN encoder interface
- Three general purpose digital inputs/outputs and one analog input
- Overvoltage protection output
- Two stop switch inputs
- Two onboard status LEDs

Mechanical data

- Board size 24.0mm x 20.5mm x 3mm
- Edge castellation with 44 half-cut plated through-hole pins at 1.5mm pin pitch

Software

- TMCL remote (direct mode) and standalone operation (onboard memory for up to 2047 TMCL commands), fully supported by TMCL-IDE (PC based integrated development environment). Refer to the TMCM-1290 TMCL firmware manual for more details.
- Modbus firmware with serial Modbus RTU standard protocol stack for the RS485 interface. Refer to the TMCM-1290 Modbus firmware manual for more details.

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2 Order Codes

The standard version of the TMCM-1290 is pre-programmed with either TMCL firmware or Modbus firmware.

Order Code	Description	Size (L x W x H)
TMCM-1290-TMCL	24V/2.1A$_{RMS}$ stepper motor controller and driver module with TMCL software stack	24.0mm x 20.5mm x 3.0mm
TMCM-1290-TMCL-T	24V/2.1A$_{RMS}$ stepper motor controller and driver module with TMCL software stack	24.0mm x 20.5mm x 3.0mm
TMCM-1290-MODBUS	24V/2.1A$_{RMS}$ stepper motor controller and driver module with Modbus software stack	24.0mm x 20.5mm x 3.0mm
TMCM-1290-MODBUS-T	24V/2.1A$_{RMS}$ stepper motor controller and driver module with Modbus software stack	24.0mm x 20.5mm x 3.0mm

Table 1: TMCM-1290 Order Codes

(*-T = tape and reel version*)

3 Mechanical Dimensions

3.1 Size of the board

The board with the controller/driver electronics has an overall size of 24.0mm x 20.5mm x 3mm.
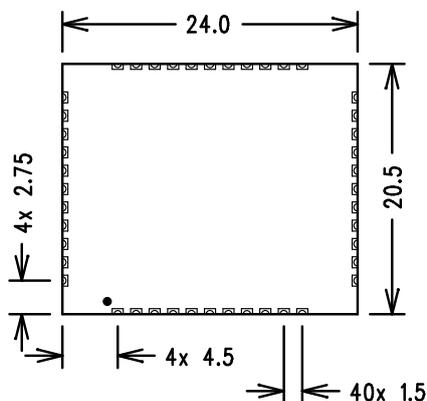
Figure 1: Board Dimensions (All Values in mm)

3.2 Board mounting considerations

The pins of the board have the dimensions of 1.0mm x 0.65mm and a pitch of 1.5mm.
The recommended pad size is 1.0mm x 1.3mm with the center positioned on the board outline such that the part extending under the board is 1:1 with the pin.

Figure 2: Pin Dimensions and recommended Pad Size (All Values in mm)

4   Pinout and Pin Descriptions

4.1   Package Pinout

Pin numbers are also printed in the top silkscreen of TMCM-1290.

Figure 3: TMCM-1290 Pinout (Top View)

4.2 Pin Table

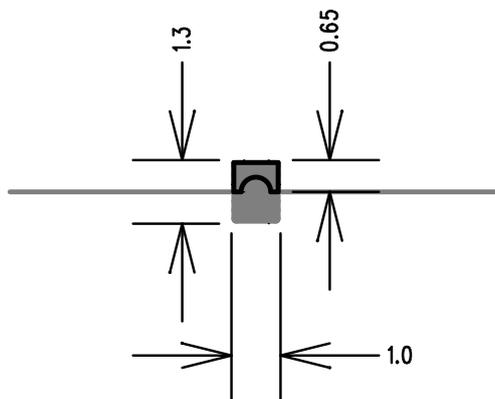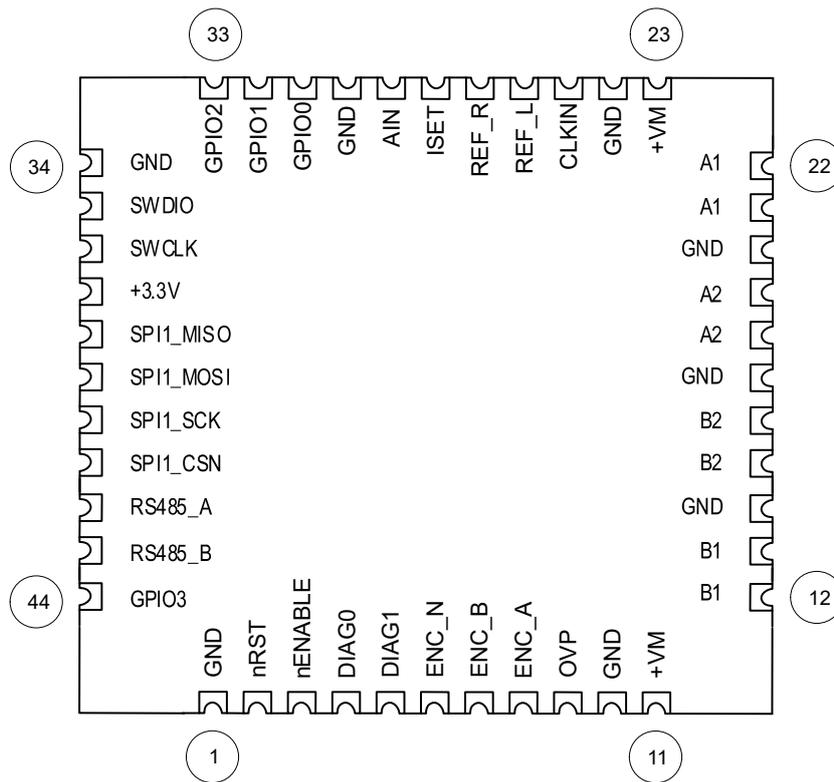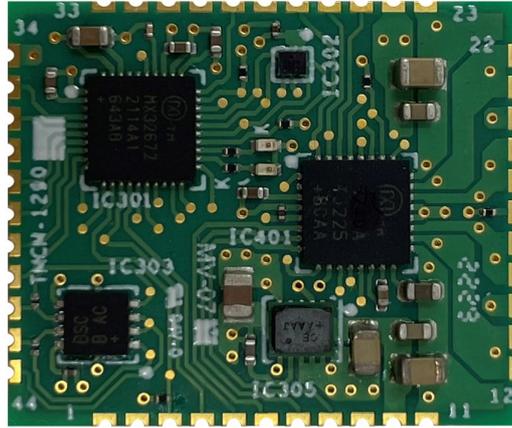| Pin Assignments				
Pin	Label	Direction	Ref Supply	Description
1, 10, 14, 17, 20, 24, 30, 34	GND	—	+VM	System ground. Connect to solid ground plane.
2	nRST	input	+3.3V	System reset input (low active)
3	nENABLE	input	+3.3V	Driver enable and standby signal. Disables driver bridges and brings driver into sleep mode (low active).
4	DIAG0	output	+3.3V	Configurable driver status/error signal
5	DIAG1	output	+3.3V	Configurable driver status/error signal
6	ENC_N	input	+3.3V	Incremental encoder input index channel
7	ENC_B	input	+3.3V	Incremental encoder input channel B
8	ENC_A	input	+3.3V	Incremental encoder input channel A
9	OVP	output	+3.3V	Overvoltage protection output. Connect to higher level controller or transistor to dump excess energy into brake resistor.
11, 23	+24V	—	+VM	Main system and driver supply. The power supply should be stabilized close to the TMCM-1290 with a low ESR electrolyte capacitor.
12, 13	B1	output	+VM	Motor phase B output
15, 16	B2	output	+VM	Motor phase B output
18, 19	A2	output	+VM	Motor phase A output
21, 22	A1	output	+VM	Motor phase A output
25	CLKIN	input	+3.3V	Optional external clock input for the stepper controller and driver. Connect to GND for using internal clock.
26	REF_L	input	+3.3V	Left reference switch input
27	REF_R	input	+3.3V	Right reference switch input
28	ISET	input	+3.3V	Full scale current setting input of motor driver. Connect external resistor between 12kΩ and 60kΩ.
29	AIN	input	+3.3V	General purpose analog input
31	GPIO0	in/out	+3.3V	General purpose IO, SW configurable
32	GPIO1	in/out	+3.3V	General purpose IO, SW configurable
33	GPIO2	in/out	+3.3V	General purpose IO, SW configurable
35	SWDIO	in/out	+3.3V	Programming and debug interface
36	SWCLK	input	+3.3V	Programming and debug interface
37	+3.3V	—	+3.3V	+3.3V supply output for external peripherals

Pin	Label	Direction	Ref Supply	Description
38	SPI_MISO	output	+3.3V	SPI communication interface serial data output (peripheral side)
39	SPI_MOSI	input	+3.3V	SPI communication interface serial data input (peripheral side)
40	SPI_SCK	input	+3.3V	SPI communication interface serial clock input (peripheral side)
41	SPI_CSN	input	+3.3V	SPI communication interface chip select input (peripheral side)
42	RS485_A	in/out	+3.3V	RS485 communication interface (non-inverted)
43	RS485_B	in/out	+3.3V	RS485 communication interface (inverted)
44	GPIO3	output	+3.3V	Leave open when using RS485 interface. If the SPI is used for communication, this pin is used as busy signal (SPI_BUSY) for handshaking with the SPI host.

Table 2: Pin Table

NOTE	**Start with power supply OFF and do not connect or disconnect the motor during operation!** Motor cable and motor inductivity 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.

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5   I/Os

<table>
<tr><td>NOTE</td><td>**The I/O voltage range is +3.3V!** TMCM-1290 has an onboard +3.3V DC/DC regulator that generates the onboard logic supply rail and provides a 200mA/+3.3V output for peripherals externally connected to the TMCM-1290. To connect to devices with different I/O voltage range, external level-shifters are required.</td></tr>
</table>

5.1   Reset Input

The nRST pin resets the entire module when pulled low. As the module is reset automatically on power up, the nRST pin can normally be left open: it is pulled high by a built-in pull-up resistor.

5.2   Enable Input

Pull the nENABLE pin low to enable the motor driver. It is pulled high by a built-in pull-up resistor when left open.

5.3   Analog Input

The AIN pin is an analog input. For analog to digital conversion, the integrated ADC of the on-board microcontroller is used with a resolution of 12 bit (0…4095). The analog input can also be used as a digital input (configurable in the software).

5.4   General Purpose Digital Inputs/Outputs

Each of the GPIO0, GPIO1, and GPIO2 pins can be configured in the software to be used either as a digital input or output. In output mode, the pin works as a push-pull output. In input mode, it is also possible to activate a built-in pull-up resistor.

5.5   Stop Switch Inputs

TMCM-1290 offers two inputs, which can be used as left (REF_L) and right (REF_R) stop switch inputs. When enabled in the software, the REF_L switch input stops motor movement in negative direction (step counter decreasing) while activated. Likewise, the REF_R switch input stops motor movement in positive direction (step counter increasing) while activated.

5.6   Incremental Encoder Inputs

An incremental A/B/N encoder may be connected to the encoder interface ENC_A, ENC_B, and ENC_N. The encoder gives positions through digital incremental quadrature signals (named A and B) and an index signal (named N).

5.7   Diagnostic Outputs DIAG0 and DIAG1

The DIAG0 and DIAG1 outputs are directly connected to the DIAG0 and DIAG1 outputs of the TMC5240. They are configured by the firmware as a position compare output and as a step output:

- DIAG0: The DIAG0 pin is used as a position compare output. Using the appropriate axis parameters in the software, this pin can be configured to output a high pulse when the motor reaches certain positions.

- DIAG1: The DIAG1 pin is used as a step output. It outputs a high pulse at every microstep.

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5.8   External Clock Input CLKIN

The CLKIN pin is directly connected to the clock pin of the TMC5240 motor driver. Either connect to ground to select the internal 12.5MHz clock or supply a 12MHz…20MHz clock signal. Typically, 16MHz is used externally.

5.9   Overvoltage Protection Output OVP

The OVP pin is directly connected to the overvoltage indicator output of the TMC5240 motor driver. Here an external MOSFET with load resistor to limit the supply voltage can be attached. In this case an external pull-up resistor is required.

5.10   Full Range Current Setting Input ISET

The ISET pin is directly connected to the IREF pin of the TMC5240 stepper motor controller and driver IC. Connect an external resistor to ground to set the analog reference current for current scaling. The range for the external resistor is 12kΩ…60kΩ. A resistor of 12kΩ results in the highest possible motor current ($3A_{peak}/2.1A_{RMS}$).

For more information and details on the current setting, refer to the TMC5240 datasheet at `https://www.analog.com/en/products/tmc5240.html`.

6   LEDs

TMCM-1290 comes with two status LEDs D1 and D2 onboard that have different functions depending on the protocol stack and firmware used.

Figure 4: TMCM-1290 LEDs

LED	Color	Bootloader Mode	TMCL Firmware	Modbus Firmware
D1	Green	on	0.5s on, 0.5s off	0.25s on, 0.25s off
D2	Red	on	off, not used	off, not used

Table 3: LED Functions

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7   System Architecture

The TMCM-1290 consists of a powerful Cortex-M4 MCU, a highly integrated and smart stepper motor controller and driver, a temperature sensor, a dedicated EEPROM, an integrated +3.3V buck regulator module, and an integrated RS485 transceiver.

The MCU is responsible for the protocol stack handling and interfacing. Various protocol stacks are available and allow for control from a dedicated host or, depending on the protocol stack, also for complete standalone operation.

The integrated stepper motor controller and driver TMC5240 includes a real-time acceleration ramp generator and extensive driver diagnostic features. In addition, an external incremental encoder can connect to the stepper motor driver and controller to monitor the motor's rotor position. While this does not allow for automatic closed loop control, the software in the MCU can take care of the position maintenance and correction.

An onboard temperature sensor allows for additional feedback of the actual board temperature to provide feedback on the system condition and ambient temperature development.

A dedicated EEPROM is available on the TMCM-1290 and connects to the MCU. The EEPROM can be used to store parameters and to let the TMCM-1290 operate in standalone mode with TMCL programs stored in the EEPROM. These TMCL programs can be started automatically after reset/power-up. The +3.3V buck regulator integrated into TMCM-1290 generates the onboard digital rail for all components and provides +3.3V for additional external peripherals or as reference for external circuits on the TMCM-1290 carrier/base board.

TMCM-1290 provides an RS485 interface as main communication interface. It can also be controlled via SPI. In SPI mode, the TMCM-1290 acts as a peripheral on the SPI bus.
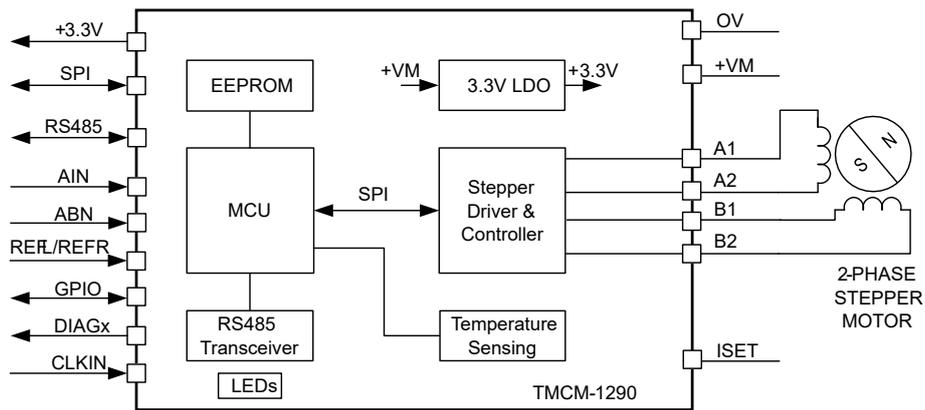

Figure 5: TMCM-1290 System Architecture

7.1   Supported Protocols and Interfaces

TMCM-1290 comes with two precompiled software options. Versions supporting TMCL and Modbus are available. Communication is done using the RS485 bus interface (TMCM-1290 has an onboard transceiver) or through SPI (peripheral interface).

Every supported protocol comes with a dedicated firmware manual, which is available from the product website.

7.1.1   TMCL Protocol Version

The TMCL operating system enables rapid development of a complete drive system within the given application, eliminating the time and engineering resources necessary to develop complicated control and

communication software. All parameters for motion control, global functions, and the GPIOx/AIN can be configured and used to adapt to the specific requirements.

The TMCL firmware allows for both standalone and direct mode operation. TMCL programs can be stored on the on-board EEPROM. Programs stored on the EEPROM can be executed automatically after power-up or when triggered by the system host.

The TMCL software running on the microprocessor of the TMCM-1290 consists of two parts, a boot loader and the firmware itself. Whereas the boot loader is installed during production testing at ADI Trinamic and remains untouched throughout the whole lifetime, the firmware can be updated by the user. New versions can be downloaded from the product website.

TMCM-1290 supports TMCL direct mode (binary commands) as well as standalone TMCL program execution. This makes it possible to write TMCL programs using the TMCL-IDE and store them in the memory of the module.

In direct mode, the TMCL communication over RS485 and SPI follows a strict host/peripheral relationship. That is, a host computer (for example PC/PLC) acting as the interface bus host sends a command to TMCM-1290The TMCL interpreter on the module interprets this command, does the initialization of the motion controller, reads inputs and writes outputs or whatever is necessary according to the specified command. As soon as this step is been done, the module sends a reply over the interface to the bus host. Only then should the host transfer the next command. Normally, the module just switches to transmission and occupies the bus for a reply, otherwise it stays in receive mode. It does not send any data over the interface without receiving a command first. This way, any collision on the bus is avoided when there are more than two peripherals connected to a single bus.

The Trinamic Motion Control Language (TMCL) provides a set of structured motion control commands. Every motion control command can be given by a host computer or can be stored in an EEPROM on the TMCM-1290 to form programs that run standalone on the module. For this purpose, there are not only motion control commands but also commands to control the program structure (like conditional jumps, compare, and calculations). Every command has a binary representation and a mnemonic. The binary format is used to send commands from the host to a module in direct mode, whereas the mnemonic format is used for easy usage of the commands when developing standalone TMCL applications using the TMCL-IDE (Integrated Development Environment). A set of configuration variables for the axis and for global parameters allow individual configuration of nearly every function of a module.

More information on TMCL, available commands, axis parameters, and example code is given in the TMCM-1290 TMCL firmware manual.

7.1.2   Modbus Protocol Version

The Modbus protocol version only supports remote controlled mode. Standalone operation is not supported. Given this, a Modbus host is always required.

More information on the Modbus protocol version is given in the TMCM-1290 Modbus firmware manual.

8   Typical Application Circuits

8.1   Minimum External Components

As TMCM-1290 contains most parts and is nearly completely self-contained, only few additional components are needed on a base board. The minimum external components are shown in Figure 6.
On a baseboard, only the external connectors are needed (depending on the application or preferences) and the resistor for the full scale current range setting on the ISET pin.
An additional capacitor on the supply is recommended to stabilize the system supply. This can be an 35V electrolyte cap of 150μF to 300μF. A low ESR type is recommended.
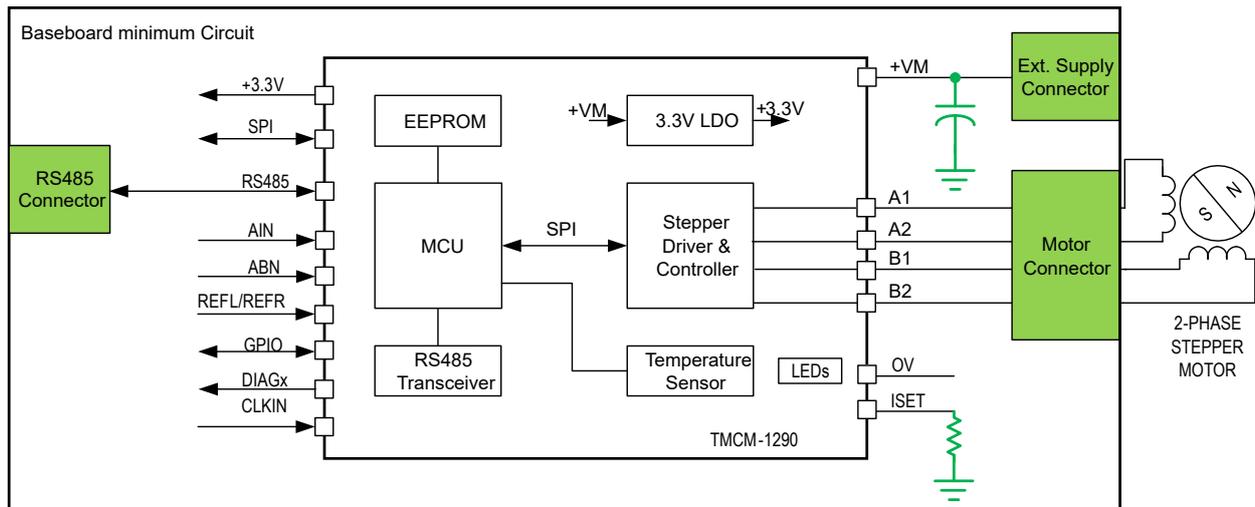

Figure 6: TMCM-1290 Minimum Application Circuit

8.2   Extended External Components

In addition to the minimum application circuit in Figure 6, the diagram in Figure 7 shows additional circuit blocks in blue.
The external communication interface may use additional protection measures and isolated transceivers or buffers.
The motor phase outputs could be equipped with filter circuits to improve EMI behavior, if required in the application.
All digital and analog I/Os may be equipped with filter stages (high, low, band passes), protection circuits, or level shifters to adapt to specific input signal characteristics and convert to the allowed input levels of TMCM-1290 .
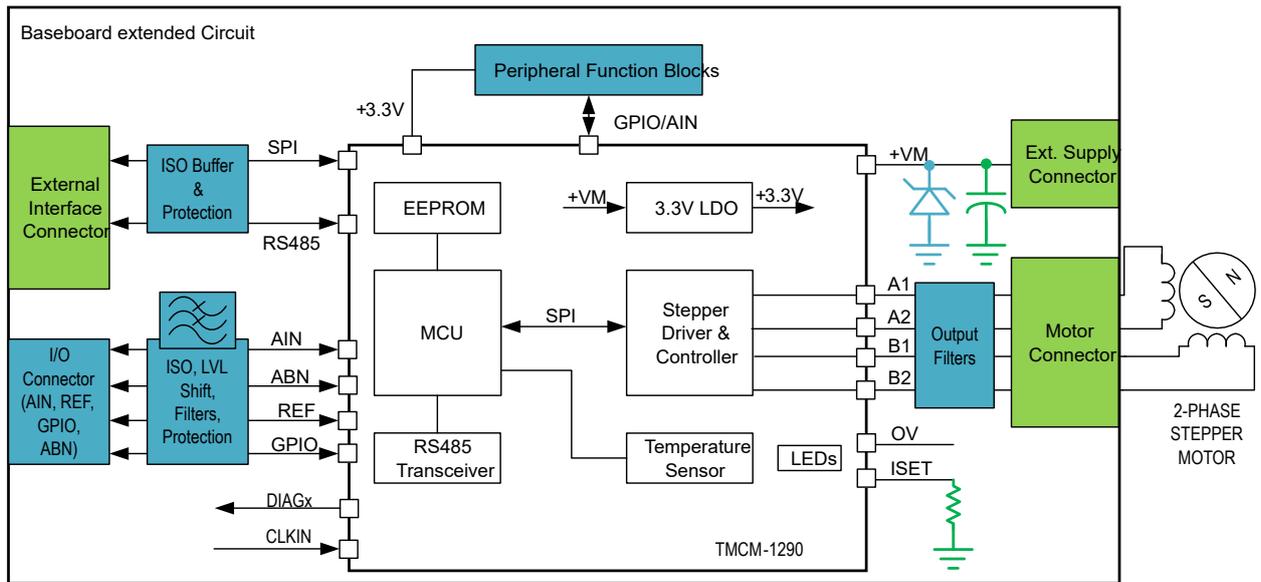With the +3.3V provided by TMCM-1290 additional peripheral blocks can be supplied.

Figure 7: TMCM-1290 Extended Application Circuit

9 Communication

9.1 RS485

For remote control and communication with a host system, the TMCM-1290 provides a two-wire RS485 bus interface. For proper operation, consider the following items when setting up an RS485 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.
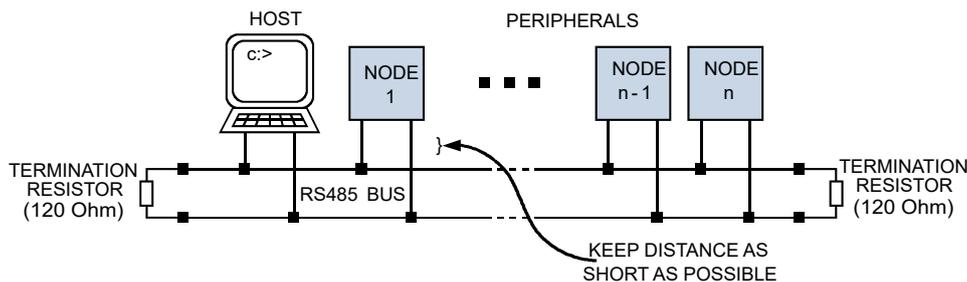

Figure 8: RS485 Bus Structure with Termination Resistors

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-1290 does not integrate any termination resistor. Therefore, 120Ωtermination 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. The bus transceiver used on the TMCM-1290 units (MAX22501) offers a significantly reduced bus load compared to the standard and allows a maximum of 255 units to be connected to a single RS485 bus using standard TMCL firmware.
   Usually, reliable communication and maximum supported communication speed cannot be expected at the same time with the maximum number of nodes connected to one bus. Instead, a compromise has to be found between bus cable length, communication speed, and number of nodes.

4. *COMMUNICATION SPEED:*
   The maximum RS485 communication speed supported by the TMCM-1290 hardware is 1Mb/s. Factory default is 115200 bit/s. Refer to the separate TMCM-1290 TMCL firmware manual for information regarding other possible communication speeds below the upper hardware limit.

5. *NO FLOATING BUS LINES:*
   Avoid floating bus lines while neither the host nor one of the peripherals 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 recommended options:
   a) Add a resistor (bias) network on one side of the bus only. A 120Ωtermination resistor is still required at both ends.
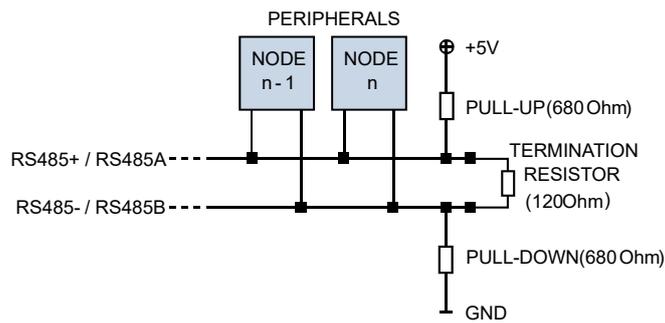
Figure 9: RS485 Bus Lines with Resistor (Bias) Network on one Side only

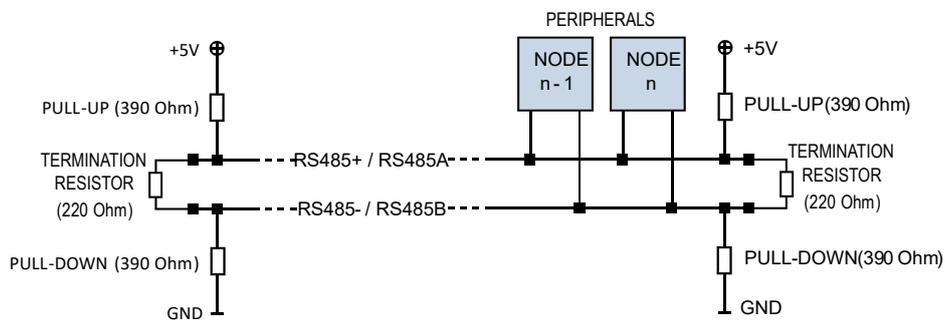b) Add a resistor network at both ends of the bus in addition to the 120Ωtermination resistors.

Figure 10: RS485 Bus Lines with dual Resistor network Line Termination

9.2   SPI

The TMCM-1290 module is also equipped with an SPI. Instead of the RS485 interface, this interface can also be used for controlling the TMCM-1290 module from a host microcontroller using TMCL communication. The following pins are used for the SPI:

- SPI_nCS: SPI chip select input. Pull low to select this module.

- SPI_SCK: SPI clock signal input. Connect to the SPI clock output of the host microcontroller.

- SPI_MOSI: SPI data input. Connect to the SPI serial data output of the host microcontroller.

- SPI_MISO: SPI data output. Connect to the SPI serial data input of the host microcontroller.

- GPIO3 (SPI_BUSY): SPI busy output. Connect to any digital input of the host microcontroller.

The SPI uses SPI mode 3. The SPI_MISO pin will is set to high impedance when the SPI_nCS pin is high. It is not possible to daisy-chain the TMCM-1290 with other SPI devices. Always use different chip select signals and connect the other SPI signals in parallel. When using more than one TMCM-1290 module, the SPI_BUSY signals must either be ORed together or each one needs to be connected to a separate input of the host microcontroller.

When using SPI communication, the GPIO3 pin is used as SPI_BUSY pin. At the beginning of the SPI datagram, the SPI_BUSY pin is set high. After the command is processed by the module (which can take between 0.1ms and 5ms, depending on the command), the SPI_BUSY pin is set low again. It is not allowed to send any SPI data while the SPI_BUSY pin is high. This internally overwrites the result of the last command or even overwrites a command that is not yet processed. Before sending any new SPI datagram, always wait until the SPI_BUSY pin has gone low again.

10 Reset to Factory Defaults

It is possible to reset all settings in the firmware for the TMCM-1290 to factory defaults without establishing a working communication connection. This might be helpful in case communication parameters of the preferred interface have been set to unknown values or got lost.
For this procedure, the pins SWDIO and SWCLK need to be shorted (electrically connected with each other) during power-on.
Perform the following steps:

1. Switch the power supply OFF.

2. Short the SWCLK and SWDIO pins.

3. Switch the power supply ON again.

4. Wait until the on-board red and green LEDs start flashing fast (this might take some seconds).

5. Switch the power supply OFF again.

6. Remove the short between the SWCLK and SWDIO pins.

7. After switching power supply ON again, wait until the green LED is flashing normally again (this may take some seconds). The module now runs with factory default settings.

11 Operational Ratings and Characteristics

11.1 Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Unit
V_{VM}	Supply voltage	-0.5	+41	V
I_{COIL_PEAK}	Motor coil peak current		3	A
I_{COIL_RMS}	Continuous motor RMS current		2.1	A
A1, A2, B1, B2	Motor output pins voltage range	-0.5	+41	V
	All other pins voltage range	-0.3	4	V
T_{ENV}	Environmental temperature at rated current (no forced cooling required)	-30	+60	° C

Table 4: Absolute Maximum Ratings

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.

11.2 Operational Ratings

Symbol	Parameter	Min	Typ	Max	Unit
V_M	Supply voltage	+4.5	+24	+36	V
I_{Power}	System supply current		$\ll I_{COIL\_RMS}$	1.4 x I_{COIL_RMS}	A
$V_{I/O}$	I/O voltage range	0		+3.3	V
$V_{+3.3V}$	External supply voltage		+3.3		V
$I_{V+3.3V}$	External supply voltage max current draw			200	mA
nENABLE					
V_{IL}	Input low voltage			0.6	V
V_{IH}	Input high voltage	0.8			V
R_{PU}	Pull-up resistance		4.7		kΩ
nRST, SWD, SPI, GPIOx, ENC_x, REF_x, OVP, CLKIN, DIAGx					
V_{IL}	Input low voltage			1	V
V_{IH}	Input high voltage	2.3			V
V_{OL}	Output low voltage			0.4	V
V_{OH}	Output high voltage	2.9			V

RS485						
V_{OD}	Differential output voltage	1.5			V
V_{OC}	Common-mode output voltage		1.65	3	V
V_{CM}	Common-mode voltage range	-15		15	V
V_{TH_H}	Differential input high voltage	50		200	mV
V_{TH_L}	Differential input low voltage	-200		-50	mV
AIN						
V_{AIN}	Voltage range	0		3.3	V
	Resolution		12		bits
ISET						
R_{ISET}	Resistor range	12		60	kΩ
V_{ISET}	Output voltage	0.882	0.9	0.918	V

Table 5: Operational Ratings

12 Figures Index

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13   Tables Index

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14 Supplemental Directives

14.1 Producer Information

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14.4 Target User

The documentation provided here, is for programmers and engineers only, who are equipped with the necessary skills and have been trained to work with this type of product.

The Target User knows how to responsibly make use of this product without causing harm to himself or others, and without causing damage to systems or devices, in which the user incorporates the product.

14.5 Disclaimer: Life Support Systems

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14.7   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.

15   Revision History

15.1   Hardware Revision

Version	Date	Description
V1.0	2022-OCT-07	Initial version

Table 6: Hardware Revision

15.2   Document Revision

Version	Date	Description
0	11/23	Initial release version
1	04/24	Order codes updated

Table 7: Document Revision