Evaluation Board User Guide

TMC6460-EVKIT

Evaluation Kit for TMC6460 – A Fully-Integrated Servo Drive IC for BLDC Motors

General Description

The TMC6460-EVKIT includes the TMC6460-EVAL board, as well as the Eselsbruecke, and Landungsbruecke interface boards, to be used together as part of the ADI Trinamic™ TMCL ecosystem.

The *TMC6460* is the first fully-integrated servo drive IC, which includes field oriented control (FOC) controller, power stage, current sensing, and feedback engine, all in one chip. Its highly-integrated design enables the control of FOC torque, velocity, and position motion with unrivalled miniaturization.

In the TMC6460, the FOC algorithm and motion control are implemented in hardware, which results in outstanding dynamic control of the motor compared to software-controlled solutions.

The high PWM frequency capabilities of the TMC6460 enable it to efficiently drive low inductance and coreless precision motors.

The TMC6460 is a flexible and easy-to-use solution, which makes it the ideal choice in applications in which precise positioning and fast acceleration are required.

The TMC6460-EVAL board allows using the TMC6460 as part of the ADI Trinamic™ evaluation board system, for example, in combination with the TMCL-IDE, or together with the PyTrinamic Python package.

Features and Benefits

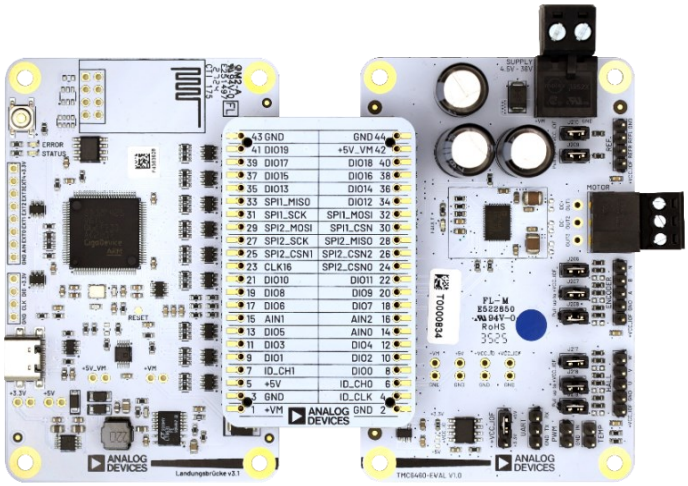
- Highly Miniaturized Servo Drive SoC
  - Drives 36V BLDC and DC Motors
  - Up to $3A_{RMS}$ and $5A_{FS}$ Current Capability
- High-Performance Motion Control
  - Hardware-Based FOC
  - Up to 200kHz Control Loop and PWM Engine
  - Embedded 8-Point Ramp Controller
  - Flexible Feedback Engine (ABN, SinCos, Digital/Analog Hall, SPI Encoders)
- Integrated Power Stage and Signal Conditioning
  - Three 36V Half Bridges with 55mΩ/FETs
  - Integrated Scalable, Lossless Current Sensing
  - Accurate CSA and ADCs
  - Short-Circuit and Thermal Protection

TMC6460-EVKIT Contents

ITEM	DESCRIPTION
TMC6460-EVAL	TMC6460 Evaluation Board
Landungsbruecke	PC Interface Board
Eselsbruecke	Bridge Connection Board

***Ordering Information* appears at end of user guide.**

Evaluation Kit Photo



319-101153; Rev. 0; 3/26

DOCUMENT FEEDBACK

TECHNICAL SUPPORT

One Analog Way, Wilmington, MA 01887-2356, U.S.A. | Tel: 781.329.4700

Getting Started

Required Material

- TMC6460-EVAL (included)
- Landungsbruecke board (included) with the latest *TMC-EvalSystem* firmware
- Eselsbruecke board (included)
- BLDC motor (max. $3A_{RMS}$)
- Power supply (4.5V to 36V; power connector included in the kit)
- Cables to interface the motor, peripherals and power supply
- USB-C data cable
- PC with the latest *TMCL-IDE* (the integrated development environment for ADI Trinamic™ modules and chips)
- *TMC6460* data sheet
- TMC6460-EVKIT user guide

Precautions

- Follow the safe electrostatic discharge (ESD) practices.
- Ensure the working area is nonconductive to prevent shorting of exposed pins on the underside of circuit boards.
- Do not exceed the board's maximum rated supply voltage.
- Do not connect or disconnect the motor while the board is powered.
- Make sure that the used board, cables, and motor are in a good state before using them.
- Do not touch the power stage section of the board during operation as it might get hot.
- Do not touch the IC on the board.

Connecting the Peripherals and First Power On

To connect the peripherals and first power on, do the following steps:

1. Unpack the Landungsbruecke, Eselsbruecke, and TMC6460-EVAL boards. Inspect the boards to ensure that no damage occurred during shipment. Connectors for motor output and power supply, as well as pin header jumpers are preinstalled.
2. Interface the TMC6460-EVAL board with the Landungsbruecke through the Eselsbruecke bridge board, as shown in the *Evaluation Kit Photo* section. Power must not be applied to either of the boards during this step. Make sure that the connectors are aligned row by row.
3. Plug the BLDC motor into connector J203, which is labelled as MOTOR on the board's silkscreen. Verify the correct order of the U, V, and W motor phases, which correspond respectively to outputs labeled OUT1, OUT2, and OUT3.
4. Connect the chosen motor angle feedback system to connectors J204 and/or J216. For more details, see the following sections.
5. Connect the Landungsbruecke board to the computer through a USB cable.
6. Plug the power supply cable into connector J202, which is labelled as SUPPLY on the board's silkscreen. Make sure that the power supply is off and the polarity of the cables is correct before plugging it to the board.
7. Turn on the power supply.

Feedback Connection Guide

The labels shown on the silkscreen of J204 and J216 (ENCODER and HALL, respectively) correspond to the default pin configurations of the TMC6460. However, an alternate function can be assigned for most pins through the TMC6460's flexible I/O matrix, which allows interfacing other types of angle feedback. For more details, refer to the TMC6460 data sheet.

Follow these steps to connect the chosen feedback system to the board. Use *Figure 2*, *Table 2*, and *Table 3* as a reference to locate the connectors and jumpers mentioned here:

1. Through the jumper at J220, select the appropriate voltage level for V_{CC_IOF} according to the feedback's requirements.
2. Connect the feedback system to the designated pin headers on the board according to *Table 1*.
3. Install (or leave if not removed) the pull-up jumpers of the used pins if using a digital Hall sensor or an ABN encoder. Remove the pull-up jumpers if using an analog Hall sensor, SinCos encoder, or SPI encoder.

Table 1. Feedback Default Connection

PIN HEADER	SILKSCREEN LABEL		PULL-UP JUMPER	DIGITAL HALL SENSOR	ABN ENCODER	ANALOG HALL SENSOR	SinCos ENCODER	SPI ENCODER	SSI ENCODER
J216	HALL	U	J219	U		U	X		
		V	J218	V		V			
		W	J217	W		W	Y	CSN	(CSN)
J204	ENCODER	A	J208		A			SCK	SCK
		B	J207		B			Encoder's SDO	Encoder's SDO
		N	J206		N			Encoder's SDI	

Note: The connection guide shown in Table 1 is based on the settings as configured by the guided Wizard of the TMCL-IDE. However, further connection options are available if the TMC6460 is manually configured.

TMCL-IDE Quick Start

Make sure that the latest version of the TMCL-IDE is installed on the computer. If using a Landungsbruecke other than the one included in the TMC6460-EVKIT, it is recommended to flash it with the latest *TMC-EvalSystem*. The included Landungsbruecke should already have the firmware to correctly work with the TMC6460.

Open the TMCL-IDE, the board should be automatically detected and appear on the **Device** tree, as shown in the left side of *Figure 1*. If automatic detection does not trigger, then manually select the motion controller board by clicking on Landungsbruecke on the **Device** tree, and choose the TMC6460-EVAL on the opened window, as shown in the right side of *Figure 1*.

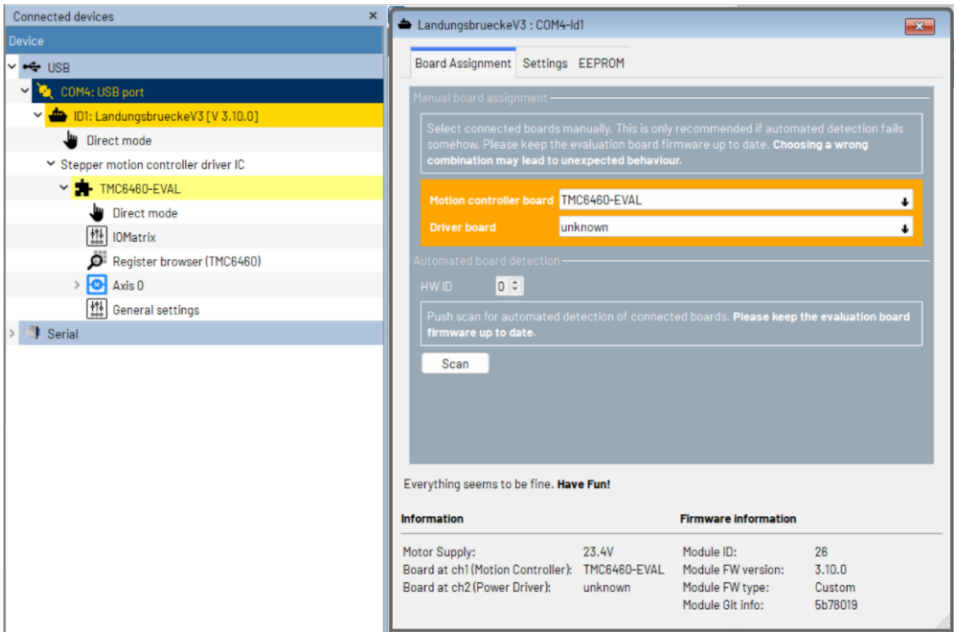


Figure 1. TMCL-IDE, Device Tree and Manual Selection of a Board

A step-by-step guided flow to configure the TMC6460 with the connected motor and feedback system is provided by the Wizard flow. To start it, click on the **Tools** menu of the menu bar and click on **Wizard Pool**. Once the Wizard launches, simply follow the steps presented in it.

For further instructions and clarifications on how to use the TMCL-IDE, refer to the TMCL-IDE manual, which can be accessed by clicking on the **Help** menu on the menu bar.

Hardware Description

The component placement drawing of the TMC6460-EVAL is shown in *Figure 2*. A description of the available connectors and configuration jumpers is shown in *Table 2* and *Table 3*, respectively.

For the schematics, bill of materials, and other fabrication drawings with relevant details, see the *Appendix* section.

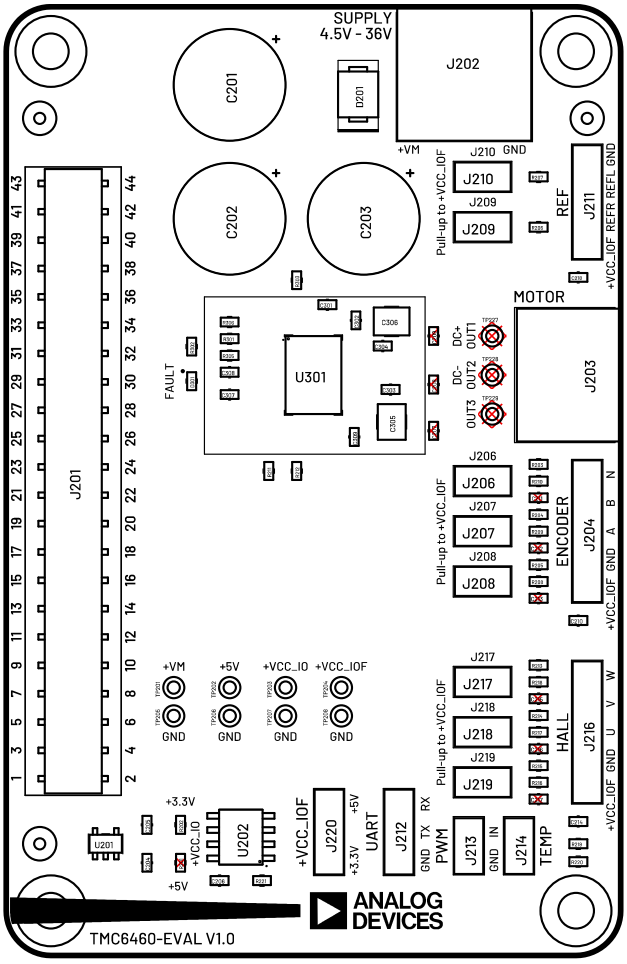


Figure 2. TMC6460-EVAL Component Placement Drawing

Table 2. TMC6460-EVAL Available Connectors

REF. DESIGNATOR	SILKSCREEN LABEL	CONNECTOR TYPE	DESCRIPTION
J201		2.54mm female pin header 22 × 2 (W+P 46-3492-44-3-00-10-PPTR)	Main IO connector to interface with the Landungsbruecke controller through the Eselsbruecke bridge board.
J202	SUPPLY 4.5V - 36V	Terminal block 2-positions, (Molex 395221002)	Main power supply input. This connector is rated for a current of up to 10A.
J203	MOTOR	Terminal block 3-positions, (Molex 395021003)	Out 1, Out 2, and Out 3 (U, V, and W, respectively) motor phase outputs.
J204	ENCODER	2.54mm pin header 5 × 1	Input for the first motor angle feedback option. The IC pins are configured for the use of a digital ABN encoder by default[1].
J211	REF	2.54mm pin header 4 × 1	Right and left reference switches input[1].
J212	UART	2.54mm pin header 3 × 1	UART interface connector[1].
J213	PWM	2.54mm pin header 2 × 1	External PWM control input[1].
J214	TEMP	2.54mm pin header 2 × 1	External temperature analog input.
J216	HALL	2.54mm pin header 5 × 1	Input for the second motor angle feedback option. The IC pins are configured for the use of a digital Hall sensor by default[1].

Note 1: The TMC6460 pins used for this connector are part of a flexible I/O matrix. The given description corresponds to the default function, but alternative assignments are available. For more details, refer to the TMC6460 data sheet.

Table 3. TMC6460-EVAL Available Jumpers

REF. DESIGNATOR	SILKSCREEN LABEL	CONNECTOR TYPE	DESCRIPTION
J206	Pull-up to +VCC_IOF	2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the ENC_N pin.
J207		2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the ENC_B pin.
J208		2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the ENC_A pin.
J209	Pull-up to +VCC_IOF	2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the REF_R pin.
J210		2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the REF_L pin.
J217	Pull-up to +VCC_IOF	2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the HALL_W pin.
J218		2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the HALL_V pin.
J219		2.54mm pin header 2 × 1	If jumper is present, make use of a pull-up resistor to V_{CC_IOF} for the HALL_U pin.
J220	+3.3V, +VCC_IOF, +5V	2.54mm pin header 3 × 1	This selects the used voltage level for the V_{CC_IOF} supply. A jumper must be present between the middle pin and either of the required voltage levels.

Power Supply and IO Voltage Selection

The TMC6460-EVAL must be powered with a supply in the range of 4.5V to 36V through the main connector J202. The supply must be capable of delivering the required current for the used motor. Make sure that the polarity of the connected cable is correct before applying any power to the board. For this purpose, +VM and GND are clearly marked on the silkscreen of the main power supply connector.

The *TMC6460* makes use of two separate IO voltage supplies, V_{CC_IO} and V_{CC_IOF}. Having this separation can be useful when the host controller uses a different voltage level than the used motor angle feedback or reference switches. To meet the requirements of a specific application, each of these voltages can be independently set on the TMC6460-EVAL to either 3.3V or 5V. The procedure to change the IO voltage supplies is given in the following sections.

V_{CC_IO} Voltage Supply

The following functionalities of the TMC6460 are referenced to the V_{CC_IO} voltage supply:

- SPI and UART communication interfaces
- External clock input
- PWM control input
- AIN analog input
- Sleep and driver enable control inputs
- External temperature analog input
- Fault control output

Note that signals for the functionalities mentioned above are interfaced with the Landungsbruecke controller through J201.

By default, the V_{CC_IO} supply is configured in the TMC6460-EVAL to use 3.3V. This is set through a 0Ω resistor, as shown in *Figure 3*. Do not change the default if using the Landungsbruecke controller, as its pins are not 5V tolerant.

If a V_{CC_IO} of 5V is required, switch the 0Ω resistor placed in R202 to the not-mounted R201. This might be required, for instance, if a controller different than the Landungsbruecke is used to control the TMC6460-EVAL.

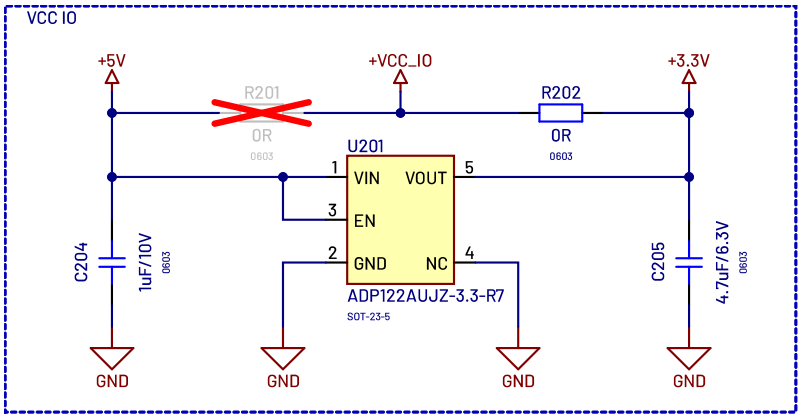


Figure 3. V_{CC_IO} Selection for the TMC6460-EVAL

Note that do not populate both R201 and R202 resistors, as this causes a short-circuit between the 5V and the 3.3V supplies.

V_{CC_IOF} Voltage Supply

The V_{CC_IOF} is an independent supply in the TMC6460, which allows the feedback signals to operate with a voltage level different than that of the control signals. The following functionalities of the TMC6460 are referenced to the V_{CC_IOF} voltage supply:

- Reference switch inputs
- Digital/analog encoder inputs
- Digital/analog Hall sensor inputs

Since none of the signals mentioned above are interfaced through the main IO connector (J201), it is possible to make use of a V_{CC_IOF} supply voltage of 5V even if the Landungsbruecke controller is used.

For convenience, V_{CC_IOF} is set in the TMC6460-EVAL through a simple pin header jumper in connector J220. To select the V_{CC_IOF} supply, simply place the included 2-position jumper from the middle pin to the pin of the required voltage level, either 3.3V or 5V. Note that no V_{CC_IOF} voltage is supplied to the IC if no jumper is present in J220.

Feedback Connectors and Signals

The TMC6460-EVAL includes connectors for up to two simultaneous motor angle feedback sources (pin headers J204 and J216), as well as two reference switch inputs (pin header J211). The *TMC6460* pins used in these connectors are all referenced to the V_{CC_IOF} supply.

As mentioned above, the feedback pins can be mapped for different functionalities through their I/O matrix alternate functions. The different functionalities configure the pins as digital inputs, digital outputs, or analog inputs. Given the flexibility of the pin configurations, the TMC6460-EVAL provides the option to connect or disconnect a pull-up resistor on each individual feedback pin. The pull-up configuration for each pin is achieved through a pin header jumper. An overview of all the available jumpers, which includes the pull-up resistor jumpers, is included in *Table 3*.

Landungsbruecke Connector and Control Signals

Connector J201 is the Landungsbruecke connector. Several control signals of the TMC6460 are interfaced with the Landungsbruecke controller, which allows communication and control of IC through a computer. The control signals going to the Landungsbruecke controller include UART and SPI communication signals, external clock input, PWM control input, sleep and driver enable control inputs, motor temperature input, and the fault control output.

Driver Enable and Sleep Inputs

In the TMC6460-EVAL, the Landungsbruecke controller handles the DRV_EN and SLEEPN pins of the TMC6460. However, pull resistors included on the board set the level of these pins to a default level.

A 4.7kΩ pull-down resistor connected to the DRV_EN pin is included onboard the TMC6460-EVAL. Therefore, the external controller is required to explicitly set a high level for the driver to be enabled.

A 4.7kΩ pull-up resistor connected to the SLEEPN pin is included onboard the TMC6460-EVAL. Therefore, the external controller is required to explicitly set a low level for the TMC6460 to enter sleep mode.

Motor Temperature Input

In addition to the IC's internal temperature sensor, the TMC6460 has an analog input for an external temperature reading on the TEMP pin. This reading can be used, for instance, to monitor the temperature of a running motor, and can optionally be used to disable the power stage in case a configurable temperature threshold is exceeded. For more details on the external temperature feature, refer to the TMC6460 data sheet.

The external temperature input is available on the TMC6460-EVAL through connector J214, as shown in *Figure 4*. To create a temperature-dependent voltage signal, connect a thermistor between V_{CC_IO} and pin 1 of J214, and attach the thermistor to the motor housing or the component whose temperature must be tracked.

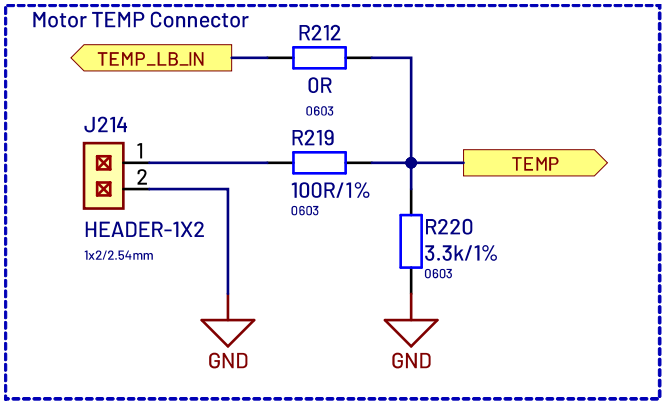


Figure 4. External Temperature Input on the TMC6460-EVAL

The resulting temperature-dependent voltage is also routed through the 0Ω resistor R212 to the main IO connector J201.

Note that the voltage at TEMP pin must not exceed the V_{CC_IO} supply level.

PWM Input

As shown in *Figure 5*, the TMC6460-EVAL includes a connection to the PWM_IN pin of the *TMC6460* through pin header J213. The PWM_IN pin can be used as an input to control the value of any register dynamically, in the so-called single-wire interface mode. This is achieved by means of a PWM signal with variable duty cycle, where the read duty cycle defines the value of the selected register.

Alternatively, the PWM_IN pin can be configured as an analog input (AIN) through the I/O matrix alternate functions. In this way, the single-wire interface can also be realized with a varying voltage level, where the read voltage value is used to dynamically control any chosen register.

For more details on the single-wire interface feature, refer to the TMC6460 data sheet.

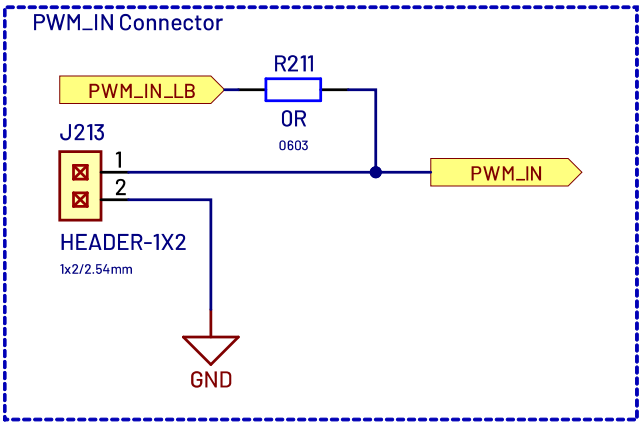


Figure 5. External PWM Control Input on the *TMC6460-EVAL*

The input signal of J213 is additionally routed through the 0Ω resistor R211 to the main IO connector J201.

Note that the voltage at the PWM_IN pin must not exceed the V_{CC_IO} supply level.

Fault Output

The TMC6460 includes a powerful fault detection system, many different fault conditions are independently detected and reported. These include motor supply undervoltage, IC overtemperature, clock fault, feedback input fault, SPI fault, among others. The fault status of the IC can be queried through the CHIP.STATUS_FLAGS and CHIP.EVENTS registers. For more details on all the detected fault conditions, refer to the TMC6460 data sheet.

In addition to the internal registers, the TMC6460 includes a FAULTN output pin. The fault output can be flexibly configured to reflect any of the available fault status flags or fault event bits, corresponding to either of the registers mentioned above. For more details on how to configure the fault output, refer to the TMC6460 data sheet.

On the TMC6460-EVAL, the FAULTN pin is connected to D301, a bright red LED. When properly configured, this allows for a clear visual indication of the chosen fault flags or event bits.

Note that the fault output does not indicate any fault condition by default, and therefore requires an explicit configuration to be set. The only instance where the output is automatically asserted is during the IC's own startup sequence. Once the TMC6460 is successfully started, the fault output is deasserted and the configuration from the registers is respected. On the TMC6460-EVAL, this behavior can be observed on LED D301, which lights up when power is applied to the board and it is turned off when the startup sequence is completed.

Ordering Information

PART	TYPE
TMC6460-EVKIT	Evaluation Kit

Appendix

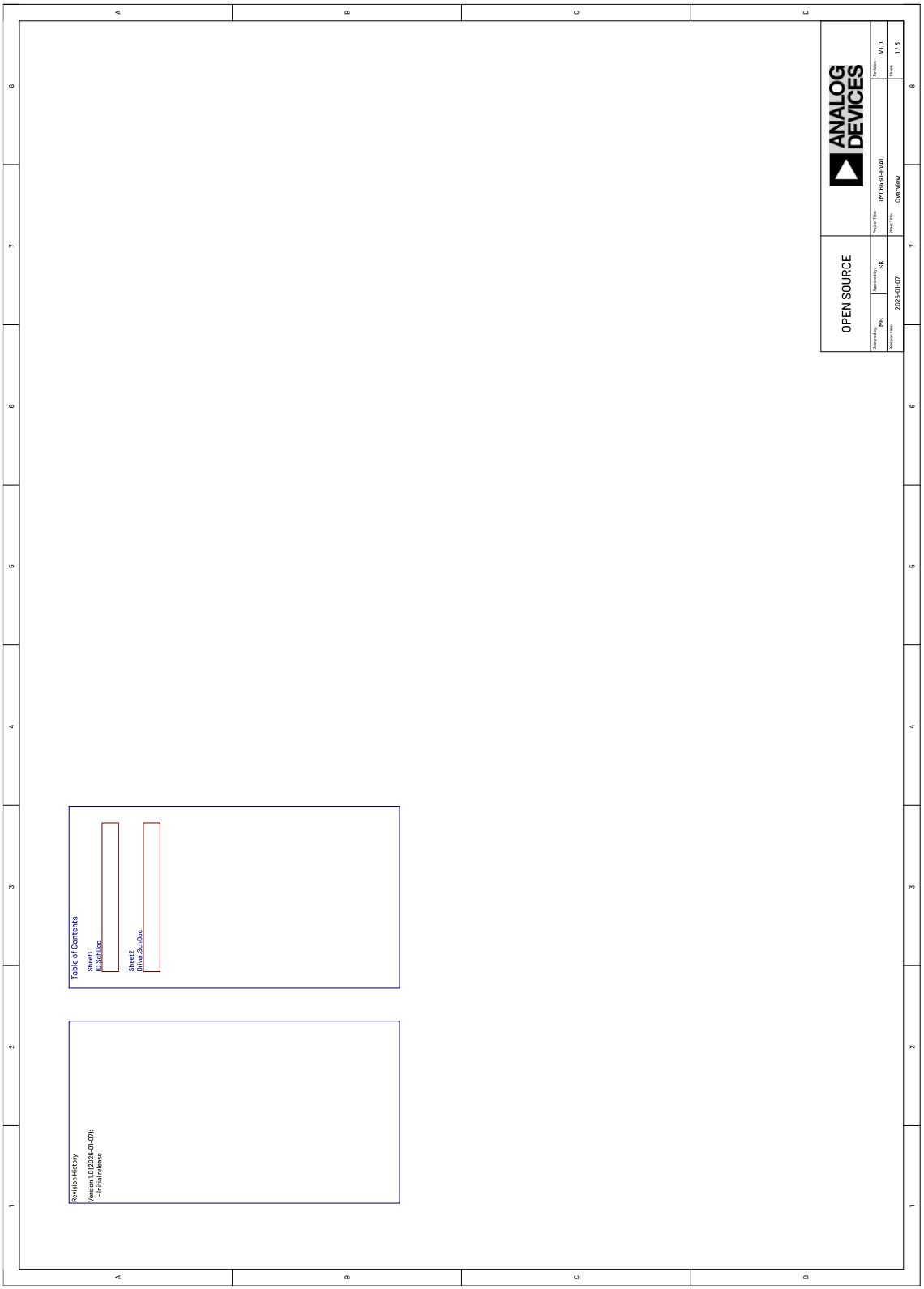
TMC6460-EVAL Bill of Materials

ITEM	REF_DES	QTY	MFG PART #	MANUFACTURER	DESCRIPTION
1	C201, C202, C203	3	EEU-FR1J271UB	Panasonic	Capacitors, through hole, 270µF, 63V, 20%
2	C204, C210, C214, C218, C308	5	0603ZD105KAT2A	Kyocera AVX	Ceramic capacitors, SMD, 1µF, 10V, 10%, X5R, 0603
3	C205	1	CL10B475KQ8NQNC	Samsung	Ceramic capacitor, SMD, 4.7µF, 6.3V, 10%, X5R, 0603
4	C206, C309	2	C0603C104K8RAC7867	Kemet	Ceramic capacitors, SMD, 100nF, 10V, 10%, X7R, 0603
5	C301	1	CC0603KPX7R9BB473	Yageo	Ceramic capacitor, SMD, 47nF, 50V, 10%, X7R, 0603
6	C302	1	C0603C105K4RAC7867	Kemet	Ceramic capacitor, SMD, 1µF, 16V, 10%, X7R, 0603
7	C303, C304	2	C0603C104K5RAC7867	Kemet	Ceramic capacitors, SMD, 100nF, 50V, 10%, X7R, 0603
8	C305, C306	2	C1210C106K5RACTU	Kemet	Ceramic capacitors, SMD, 10µF, 50V, 10%, X7R, 0603
9	C307	1	CC0603KRX7R5BB225	Yageo	Ceramic capacitor, SMD, 2.2µF, 6.3V, 10%, X7R, 0603
10	D201	1	SMBJ36A-E3/5B	Vishay General Semiconductor	Transient voltage suppressors (TVS) diode, 60W, surface mount, DO-214AA (SMBJ36A)
11	D301	1	LTST-C191KRKT	Lite-On Inc.	LED indication – discrete, red, 2V, 20mA, 0603
12	J201	1	HLE-122-02-F-DV	Samtec Inc.	Connector, 44-positions, 2 rows, gold contact finish, 2.54mm pitch
13	J202	1	395221002	Molex	Connector, header, male pins, shrouded (4-side), through hole, 5mm pitch
14	J203	1	395021003	Molex	Connector, header, male pins, shrouded (4-side), through hole, 5mm pitch
15	J204, J216	2	61300511121	Wurth Elektronik	Connectors, header, vertical, 5-positions, 2.54mm pitch
16	J206, J207, J208, J209, J210, J213, J214, J217, J218, J219	10	61300211121	Wurth Elektronik	Connectors, header, vertical, 2-positions, 2.54mm pitch
17	J211	1	61300411121	Wurth Elektronik	Connector, header, vertical, 4-positions, 2.54mm pitch
18	J212, J220	2	61300311121	Wurth Elektronik	Connectors, header, vertical, 3-positions, 2.54mm pitch
19	JMP206 to JMP210, JMP217 to JMP220	9	09200-71-BBGB00	METZ Connect USA, Inc.	Jumpers, vertical, 2-positions, 2.54mm pitch
20	PLG202	1	395200002	Molex	Connector, plug, female sockets, 2-positions, 5mm pitch
21	PLG203	1	395000003	Molex	Connector, plug, female sockets, 3-positions, 3.5mm pitch
22	R202, R211, R212	3	ERJ-3GEY0R00V	Panasonic	Resistors, SMD, 0Ω, 0.1W, 0603
23	R203, R204, R205, R206, R207, R213, R214, R215	8	ERJ-3EKF2701V	Panasonic	Resistors, SMD, 2.7kΩ, 1%, 0.1W, 0603

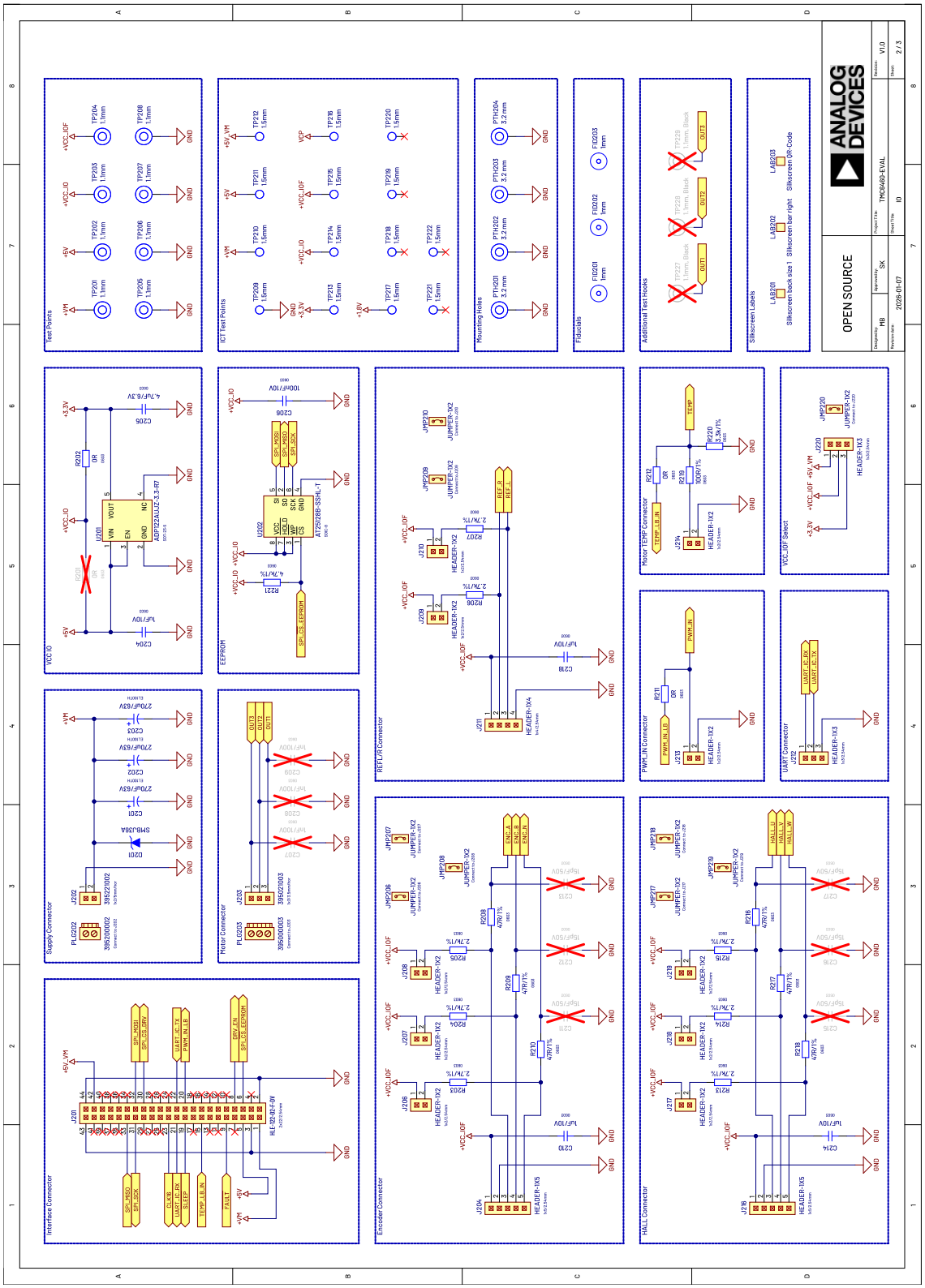
TMC6460-EVAL Bill of Materials (continued)

ITEM	REF_DES	QTY	MFG PART #	MANUFACTURER	DESCRIPTION
24	R208, R209, R210, R216, R217, R218	6	ERJ-3EKF47R0V	Panasonic	Resistors, SMD, 47Ω, 1%, 0.1W, 0603
25	R219	1	ERJ-3EKF1000V	Panasonic	Resistor, SMD, 100Ω, 1%, 0.1W, 0603
26	R220	1	ERJ-3EKF3301V	Panasonic	Resistor, SMD, 3.3kΩ, 1%, 0.1W, 0603
27	R221, R301, R303, R306	4	ERJ-3EKF4701V	Panasonic	Resistors, SMD, 4.7kΩ, 1%, 0.1W, 0603
28	R302	1	ERJ-3EKF1001V	Panasonic	Resistor, SMD, 1kΩ, 1%, 0.1W, 0603
29	R305	1	RT0603BRD0760K4L	Yageo	Resistor, SMD, 60.4kΩ, 0.1%, 0.1W, 0603
30	U201	1	*ADP122AUJZ-3.3-R7*	Analog Devices, Inc.	IC, 5.5V input, 300mA, low quiescent current, CMOS linear regulator
31	U202	1	AT25128B-SSHL-T	Microchip Technology	IC, SMD, nonvolatile, EEPROM, 128Kbit
32	U301	1	*TMC6460ATU+*	Analog Devices, Inc.	IC, fully-integrated field-oriented control brushless DC driver

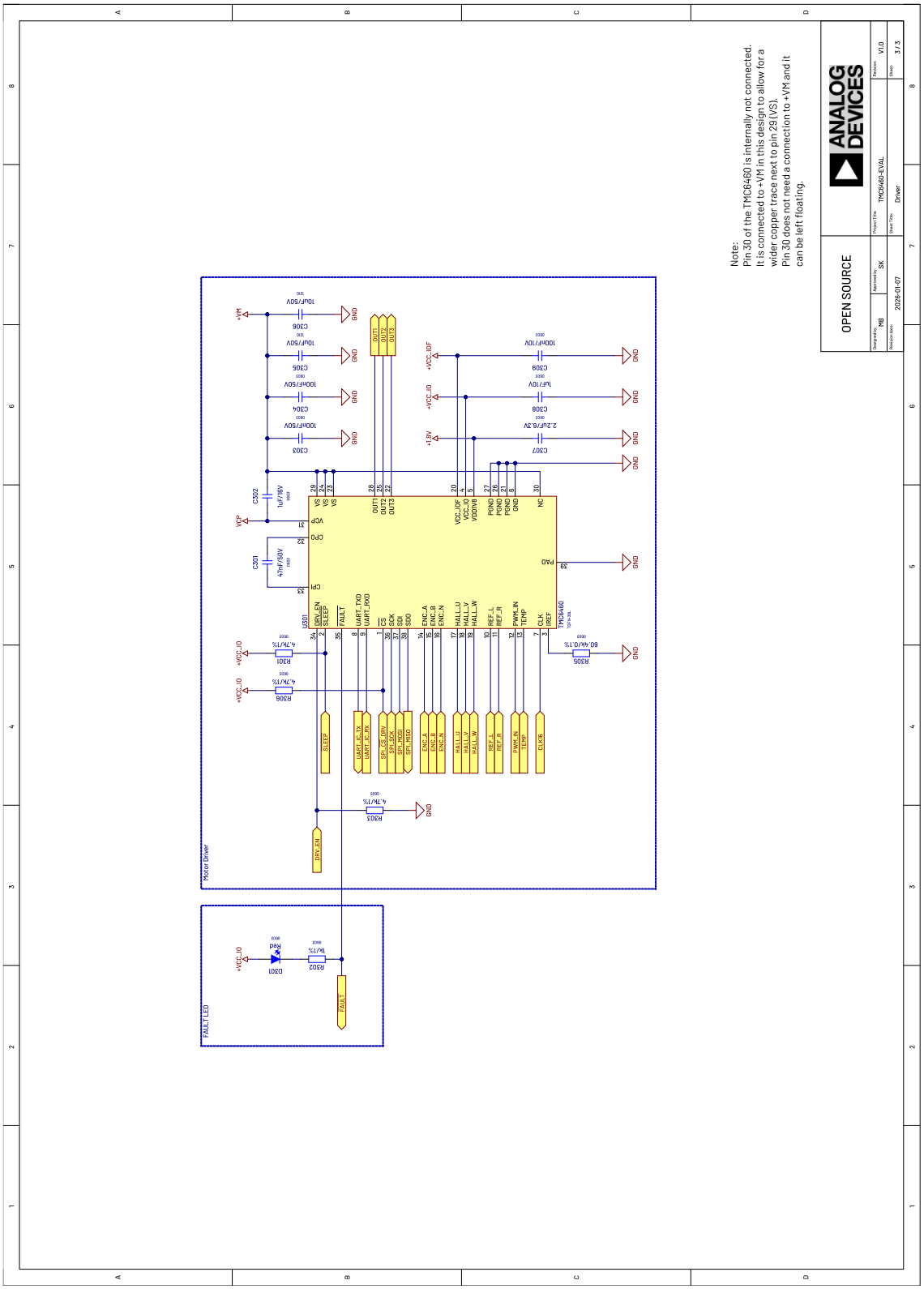
TMC6460-EVAL Schematics



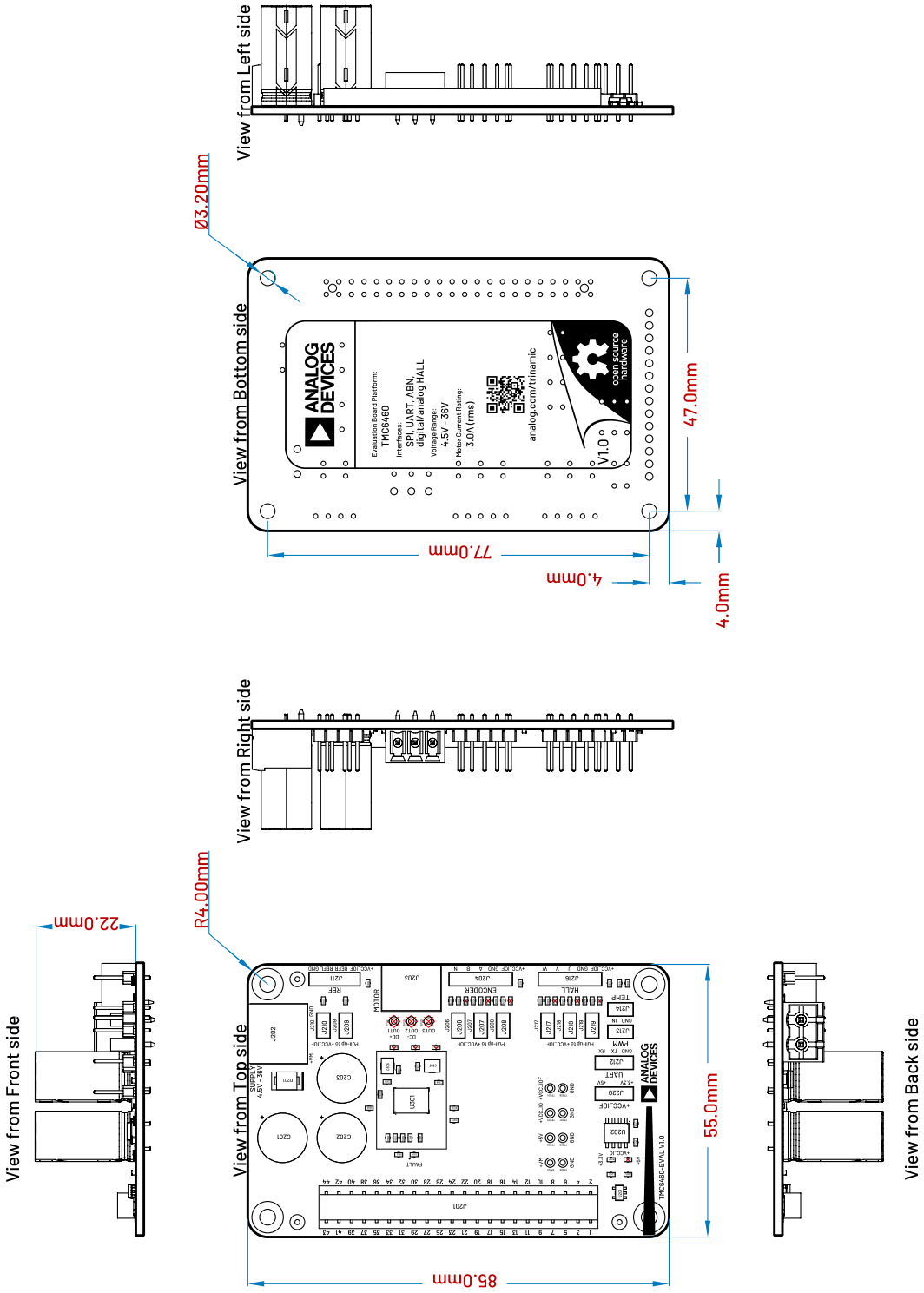
TMC6460-EVAL Schematics (continued)



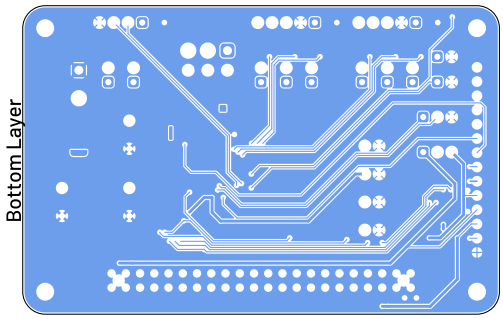
TMC6460-EVAL Schematics (continued)

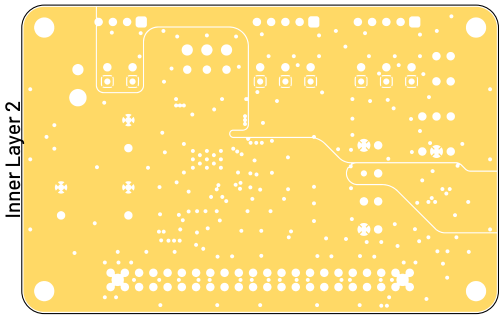


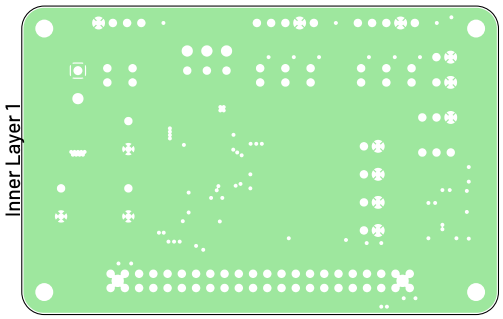
TMC6460-EVAL Mechanical Dimensions

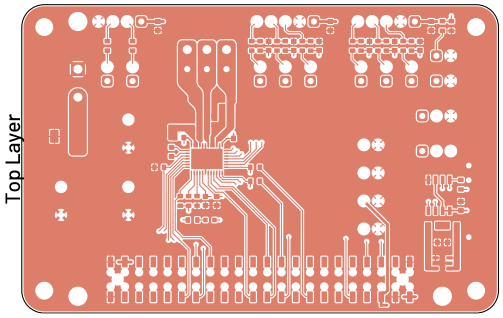


TMC6460-EVAL PCB Layout



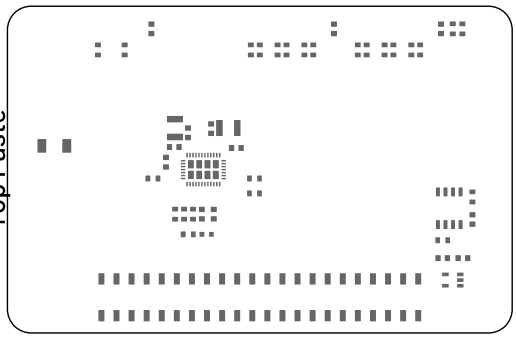




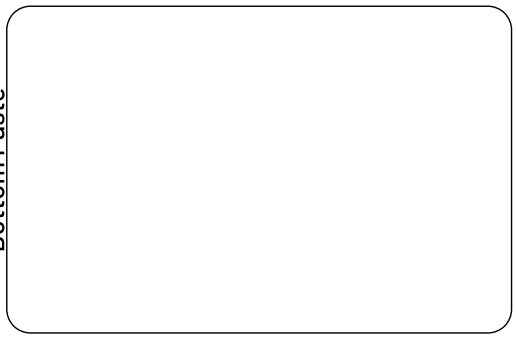


TMC6460-EVAL Additional Fabrication Layers

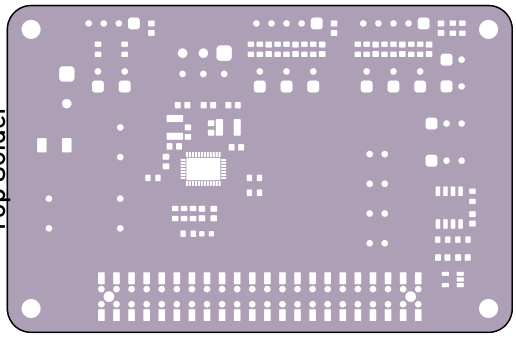
Top Paste



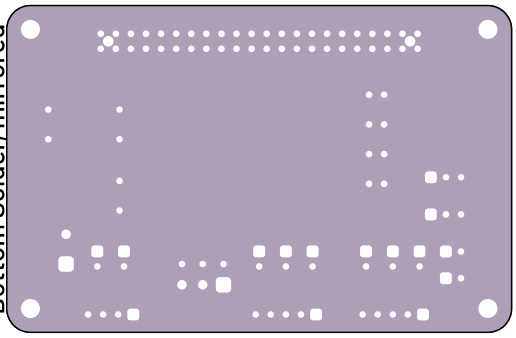
Bottom Paste



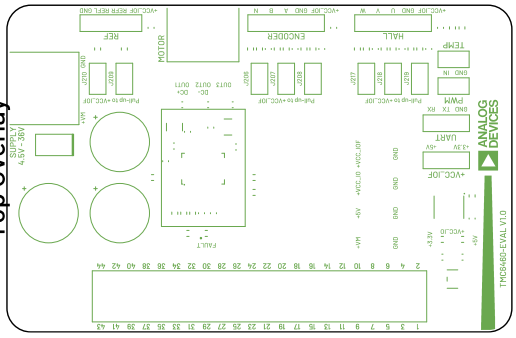
Top Solder



Bottom Solder, mirrored



Top Overlay



Bottom Overlay, mirrored

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	3/26	Initial release	—

Notes