# TMC2100 DATASHEET

Standalone intelligent Step/Direction driver for two-phase bipolar stepper motor.
StealthChop™ for quiet movement. Integrated MOSFETs for up to 2.0A motor current per coil.
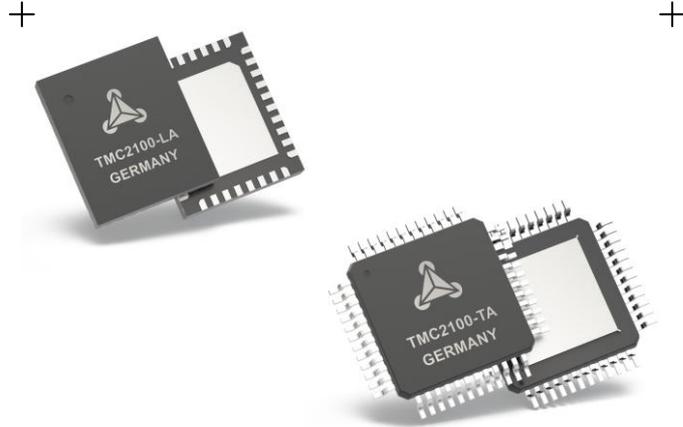
APPLICATIONS

3D printers
Textile, Sewing Machines
Office Automation
Consumer, Home
CCTV, Security
ATM, Cash recycler
POS
Printers & Scanners

FEATURES AND BENEFITS

2-phase stepper motors up to 2.0A coil current (2.5A peak)

Standalone Driver

Step/Dir Interface with microstep interpolation **MicroPlyer™**

Voltage Range 4.75… 46 V DC

Highest Resolution 256 microsteps per full step

StealthChop™ for extremely quiet operation and smooth motion

SpreadCycle™ highly dynamic motor control chopper

**Integrated Current Sense Option**

Standstill Current Reduction

Full Protection & Diagnostics (two outputs)

Small Size 5x6mm² QFN36 package or TQFP48 package

DESCRIPTION

The TMC2100 is a standalone driver IC. This small and intelligent standalone driver for two-phase stepper motors offers market-leading features while being configured by seven pins only. CPU interaction is not required. Drive the motor via Step and Direction signals. TRINAMICs sophisticated StealthChop chopper ensures noiseless operation combined with efficiency and best motor torque. Integrated power MOSFETs handle motor currents up to 1.2A RMS continuously (QFN package) / 1.4A RMS (TQFP) per coil. For saving energy, the TMC2100 provides standstill current reduction. Protection and diagnostic features support robust and reliable operation. The TMC2100 enables miniaturized designs with low external component count for cost-effective and highly competitive solutions.

BLOCK DIAGRAM

Configuration via 7 pins   I REF optional current scaling

Power Supply → +5V Regulator / Charge Pump

Configuration Interface with TRISTATE Detection

DAC Reference

TMC2100

Step/ Dir → Step Multiplyer / Standstill Current Reduction

256 µStep Sequencer

SpreadCycle™ / StealthChop™

Driver

Motor

CLK → CLK Oscillator/ Selector

Protection & Diagnostics

ERROR / INDEX

TRINAMIC Motion Control GmbH & Co. KG
Hamburg, Germany

TRINAMIC
MOTION CONTROL
Now part of Maxim Integrated

# APPLICATION EXAMPLES: SIMPLE SOLUTIONS – HIGHLY EFFECTIVE

The TMC2100 scores with power density, integrated power MOSFETs, smooth and quiet operation, and a congenial simplicity. The TMC2100 covers a wide spectrum of applications from battery systems up to embedded applications with up to 2.0A motor current per coil. TRINAMICs unique chopper modes SpreadCycle and StealthChop optimize drive performance. StealthChop reduces motor noise to the point of silence during low velocities. Standby current reduction keeps costs for power dissipation and cooling down. Extensive support enables rapid design cycles and fast time-to-market with competitive products.

### STANDALONE DESIGN FOR ONE STEPPER MOTOR
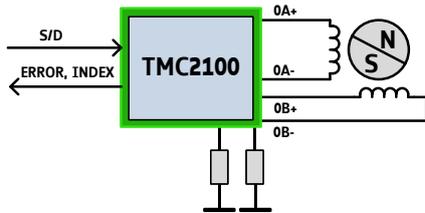
In this example, configuration is hard wired. The motor is driven via step and direction signals. Motion control tasks and interpreting ERROR and INDEX are software based.

MINIATURIZED DESIGN FOR ONE STEPPER MOTOR
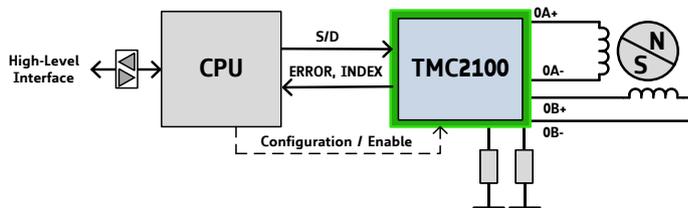
Here, the CPU sends step and direction signals to the TMC2100 and reads out ERROR and INDEX for diagnostic tasks. Further, the CPU configures the TMC2100 and manages motion control. Based on Step/Dir signals, the TMC2100 provides motor currents for each axis and smoothens and optimizes drive performance.

EVALUATION BOARD SYSTEM
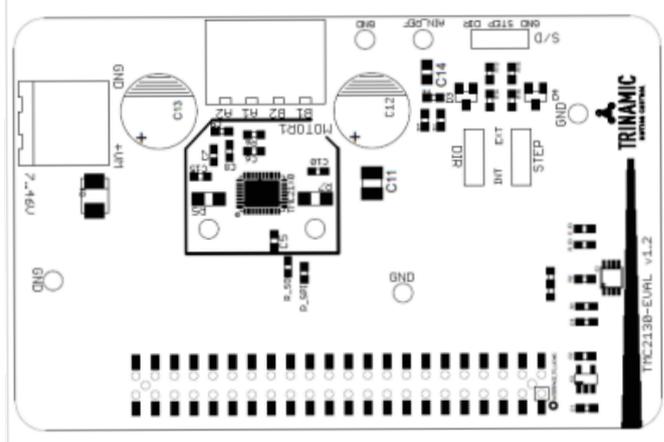
The TMC2100-EVAL is part of TRINAMICs universal evaluation board system which provides a convenient handling of the hardware as well as a user-friendly software tool for evaluation. The TMC2100 evaluation board system consists of three parts: STARTRAMPE (base board), ESELSBRÜCKE (connector board with several test points), and TMC2100-EVAL.

ORDER CODES

Order code	PN	Description	Size [mm²]
TMC2100-LA	00-0135	1-axis StealthChop standalone driver; QFN36	5 x 6
TMC2100-TA	00-0140	1-axis StealthChop standalone driver; TQFP48	7 x 7 (body)
TMC2100-xx-T	…-T	-T denotes tape on reel packed devices (xx is LA or TA)	
TMC2100-EVAL	40-0084	Evaluation board for TMC2100	85 x 55
LANDUNGSBRÜCKE	40-0167	Baseboard for evaluation board system	85 x 55
ESELSBRÜCKE	40-0098	Connector board fitting to Landungsbrücke	61 x 38

Table of Contents

1   Key Concepts

The TMC2100 is easy to use. It can be configured by seven hardware pins. CPU interaction is not necessary. The TMC2100 positions the motor based on step and direction signals and the integrated MicroPlyer automatically smoothens motion. Basic standby current control can be done by the TMC2100. Optional feedback signals allow error detection and synchronization. Optionally, current scaling is possible by providing an analog reference current IREF.

A CPU for configuration, motion control, and diagnostics can be connected, but this is not basically needed to drive the motor.
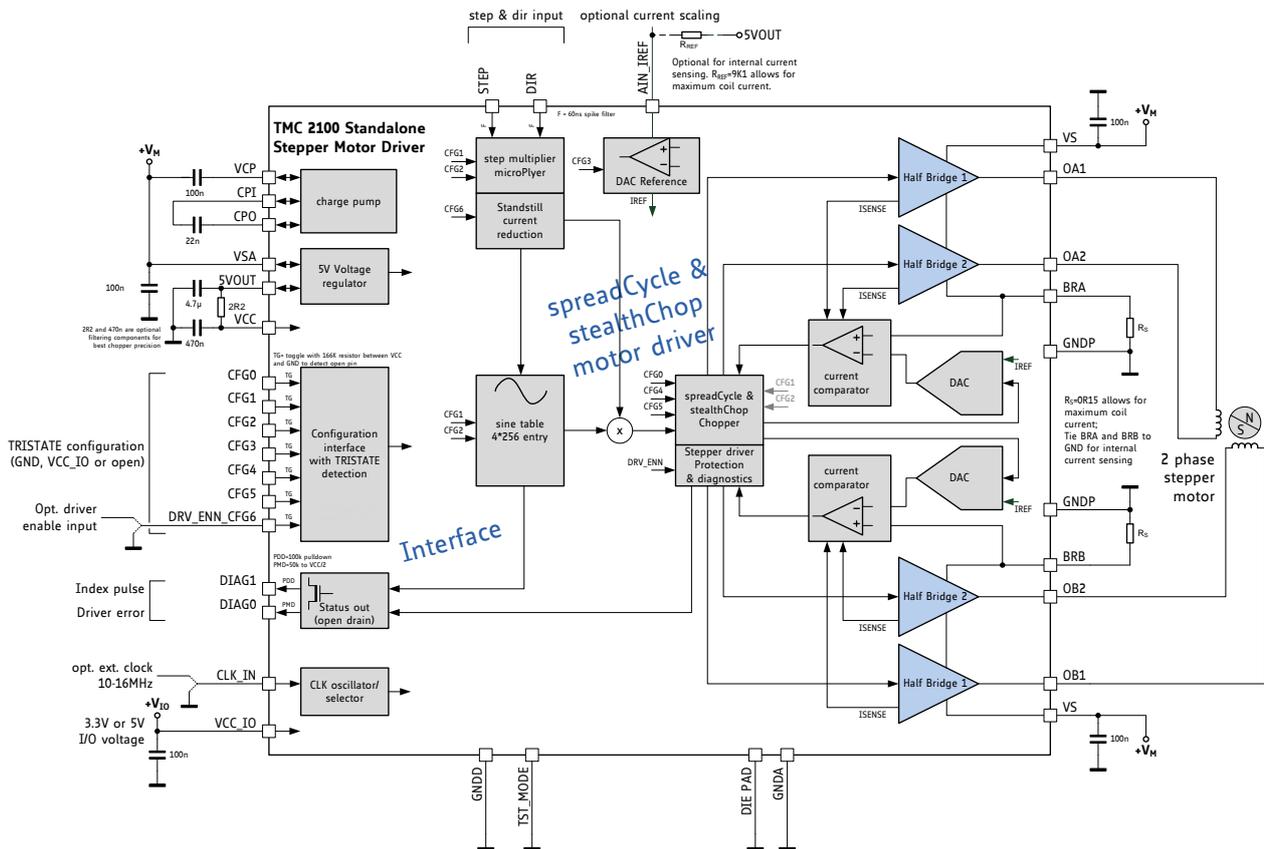
Figure 1.1 TMC2100 standalone driver application diagram

The TMC2100 implements advanced features which are exclusive to TRINAMIC products. These features contribute toward greater precision and smoother motion in many stepper motor applications. Particularly, the TMC2100 provides special chopper algorithms in order to reduce engine noise and react extremely fast to changes in velocity and motor load.

StealthChop™   is a voltage chopper based principle. It guarantees that the motor is absolutely quiet in standstill and in slow motion, except for noise generated by ball bearings. The extremely smooth motion is beneficial for many applications.

SpreadCycle™   offers smooth operation and great power efficiency over a wide range of speed and load. The SpreadCycle chopper scheme automatically integrates a fast decay cycle and guarantees smooth zero crossing performance.

MicroPlyer™   microstep interpolator for obtaining increased smoothness of microstepping.

1.1   Software

Usually, the TMC2100 is configured to a fixed configuration using the related hardware pins. Status bits for error detection can be read out using ERROR and INDEX. The TMC2100 is a stepper motor driver chip that can be driven software based with only little effort. It does not need a master CPU or a motion controller IC, but step and direction signals have to be provided to drive a motor.

1.2   STEP/DIR Interface

The motor is controlled by a step and direction input. Active edges on the STEP input are rising ones. On each active edge, the state sampled from the DIR input determines whether to step forward or back. Each step can be a fullstep or a microstep, in which there are 2, 4, 16 or 256 (interpolated) microsteps per fullstep. During microstepping, a step impulse with a low state on DIR increases the microstep counter and with a high state decreases the counter by an amount controlled by the microstep resolution. An internal table translates the counter value into the sine and cosine values which control the motor current for microstepping.

1.3   Standstill Current Reduction

The automatic standstill current reduction allows to automatically reduce the motor current by nearly two-thirds to save energy in standstill. This is possible in many applications, as normally less holding torque is required. In case the standstill current option has been enabled, the motor current becomes softly ramped down from 100% to 34% in 44M clock cycles (3 to 4 seconds) if no step pulse has been issued for more than 3M clock cycles (standby delay time). The soft current ramp avoids a jerk on the motor.
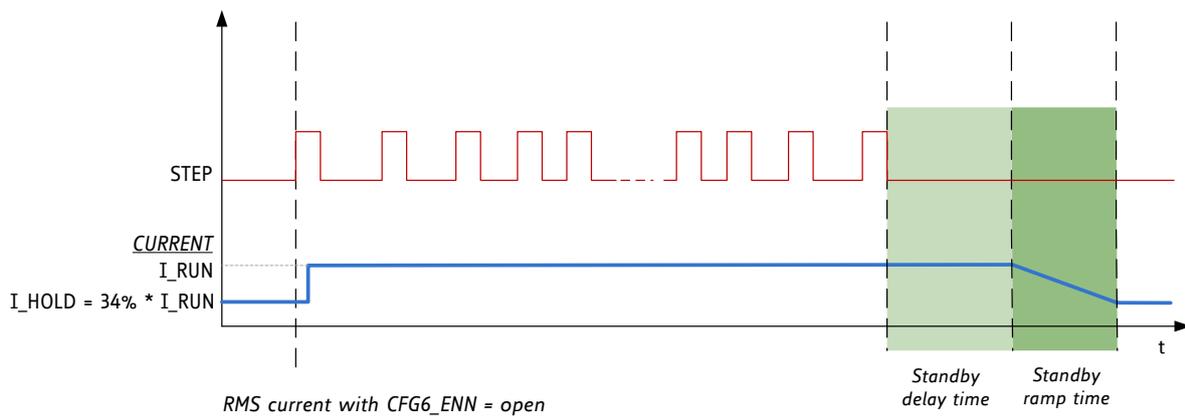
Figure 1.2 Standstill current reduction

1.4   Diagnostics and Protection

The TMC2100 offers safeguards to detect and protect against shorted outputs, overtemperature, and undervoltage conditions for enhancing safety and recovery from equipment malfunctions.

2   Pin Assignments

2.1   Package Outline
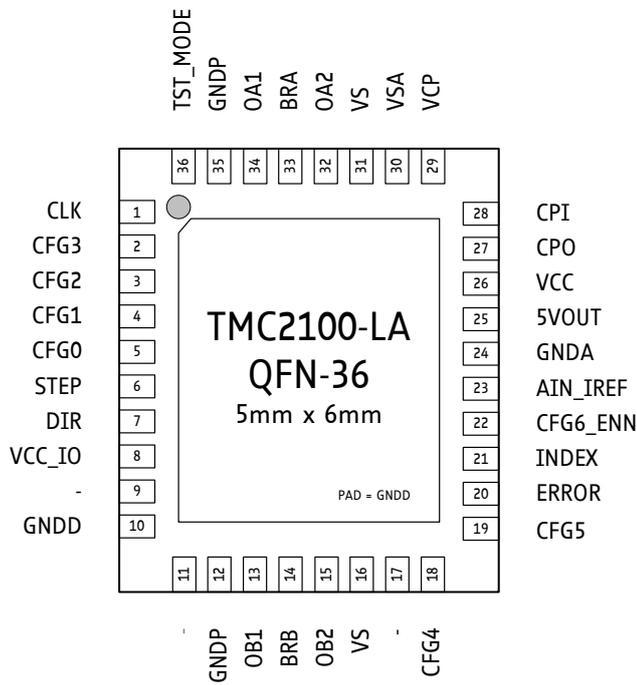
**Figure 2.1 TMC2100-LA package and pinning QFN-36 (5x6mm²)**
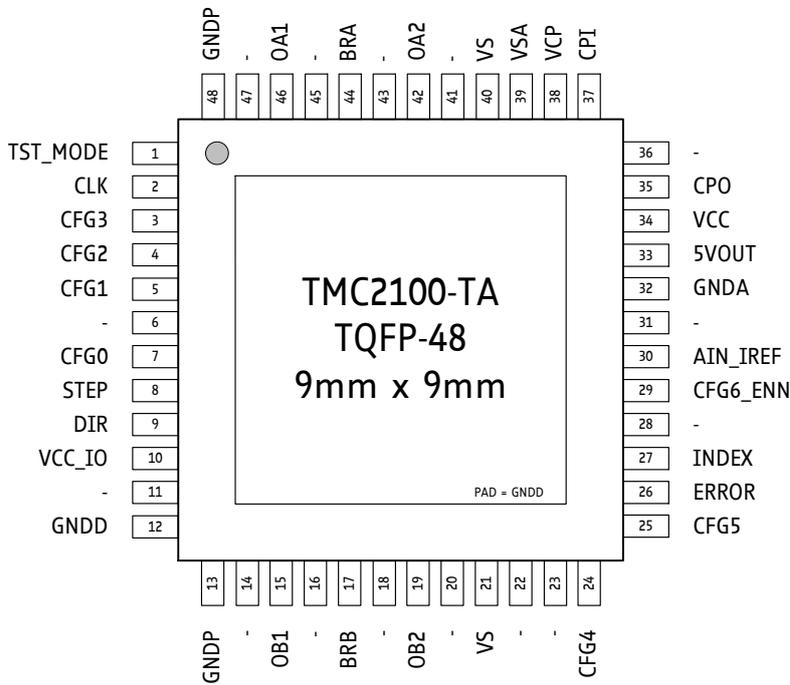
Figure 2.2 TMC2100-TA package and pinning TQFP-48 (9x9mm² with leads)

2.2 Signal Descriptions

Pin	QFN36	TQFP48	Type	Function
CLK	1	2	DI	CLK input. Tie to GND using short wire for internal clock or supply external clock.
CFG3	2	3	DI	Configuration input
CFG2	3	4	DI	Configuration input
CFG1	4	5	DI	Configuration input
CFG0	5	7	DI	Configuration input
STEP	6	8	DI	STEP input
DIR	7	9	DI	DIR input
VCC_IO	8	10		3.3 V to 5 V IO supply voltage for all digital pins.
DNC	9, 17	11, 14, 16, 18, 20, 22, 23, 28, 41, 43, 45, 47		Do not connect. Leave open!
GNDD	10	12		Digital GND. Connect to GND.
N.C.	11	6, 31, 36		Unused pin, connect to GND for compatibility to future versions.
GNDP	12, 35	13, 48		Power GND. Connect to GND plane near pin.
OB1	13	15		Motor coil B output 1
BRB	14	17		Sense resistor connection for coil B. Place sense resistor to GND near pin. Tie to GND when using internal sense resistors.
OB2	15	19		Motor coil B output 2
VS	16, 31	21, 40		Motor supply voltage. Provide filtering capacity near pin with short loop to nearest GNDP pin (respectively via GND plane).
CFG4	18	24	DI	Configuration input
CFG5	19	25	DI	Configuration input
ERROR	20	26	DO	Driver error (Open drain output with 50k resistor to 2.5V)
INDEX	21	27	DO	Microstep table position index (Open drain output with 100k pulldown resistor – use sufficient pullup resistor of 22k max.)
CFG6_ENN	22	29	DI	Enable input (high to disable) and power down configuration
AIN_IREF	23	30	AI	Analog reference voltage for current scaling or reference current for use of internal sense resistors (optional mode)
GNDA	24	32		Analog GND. Tie to GND plane.
5VOUT	25	33		Output of internal 5 V regulator. Attach 2.2 µF to 10 µF ceramic capacitor to GNDA near to pin for best performance.
VCC	26	34		5V supply input for digital circuitry within chip and charge pump. Attach 470nF capacitor to GND (GND plane). Supply by 5VOUT. Use a 2.2 or 3.3 Ohm resistor for decoupling noise from 5VOUT. When using an external supply, make sure, that VCC comes up before or in parallel to 5VOUT!
CPO	27	35		Charge pump capacitor output.
CPI	28	37		Charge pump capacitor input. Tie to CPO using 22 nF 50V capacitor.
VCP	29	38		Charge pump voltage. Tie to VS using 100 nF 16V capacitor.
VSA	30	39		Analog supply voltage for 5V regulator. Normally tied to VS. Provide a 100 nF filtering capacitor.
OA2	32	42		Motor coil A output 2
BRA	33	44		Sense resistor connection for coil A. Place sense resistor to GND near pin. Tie to GND when using internal sense resistors.
OA1	34	46		Motor coil A output 1
TST_MODE	36	1	DI	Test mode input. Tie to GND using short wire.
Exposed die pad	-	-		Connect the exposed die pad to a GND plane. Provide as many as possible vias for heat transfer to GND plane. Serves as GND pin for digital circuitry.

*) All pins of type DI, DI(pu), DI(tpu), DIO and DIO(tpu) refer to VCC_IO and have intrinsic protective clamping diodes to GND and VCC_IO and use Schmitt trigger inputs.

3   Operation

STEP/DIR inputs control the driver. The TMC2100 works in SpreadCycle mode or StealthChop mode. It provides microstep interpolation and automatic standstill current reduction. ERROR signals driver error and INDEX signals the microstep table index position (low active open drain outputs).
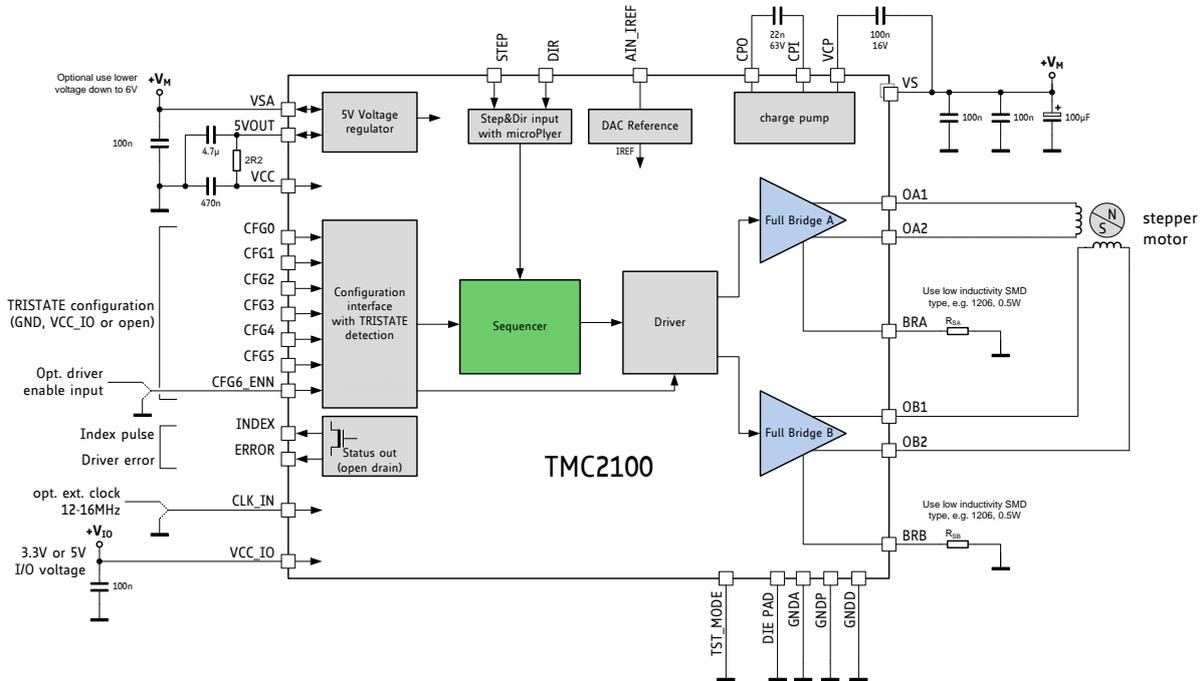
Figure 3.1 Standalone operation example circuit

3.1   CFG Pin Configuration

TMC2100 configuration is hard wired. All pins CFG0 to CFG6 are evaluated using tristate detection in order to differentiate between:

- CFG pin tied to GND
- CFG pin open (no connection)
- CFG pin tied to VCC_IO

CFG6_ENN enables the driver chip. Further, it selects whether standby current reduction is used or not.

CFG6_ENN: ENABLE PIN AND CONFIGURATION OF STANDSTILL POWER DOWN		
CFG6	**Motor driver enable**	**Standstill power down**
GND	Enable	N
VCC_IO	Disable	Driver disabled.
open	Enable	Y. Motor current ramps down from 100% to 34% in 44M clock cycles (3 to 4 seconds) after standstill detection (no step pulse for more than 1M clock). In combination with StealthChop, be sure not to work with too low overall current setting, as regulation will not be able to measure the motor current after stand still current reduction. This will result in very low motor current after the stand-still period.

Please refer to Figure 1.2 for more information about standstill power down.

A current control mode can be set with CFG3. In particular, the source for the reference voltage (on chip or external) and the method of current scaling can be chosen.

CFG3 SETS MODE OF CURRENT SETTING	
CFG3	Current Setting
GND	Internal reference voltage. Current scale set by external sense resistors, only.
VCC_IO	Internal sense resistors. Use analog input current on AIN as reference current for internal sense resistor. This setting gives best results when combined with StealthChop voltage PWM chopper.
open	External reference voltage on pin AIN. Current scale set by sense resistors and scaled by AIN.

The desired microstep resolution for the STEP input can be chosen via CFG2 and CFG1 configurations. The driver automatically uses microstep positions which result in a symmetrical wave especially when switching to a lower microstep resolution.

Note that SpreadCycle mode is possible with and without step interpolation to 256 microsteps. TRINAMIC recommends using step interpolation for achieving a smoother drive. While the parameters for SpreadCycle can be configured for best microstep performance, StealthChop has a fixed setting. CFG0 and CFG4 settings do not influence the StealthChop configuration. This way, it is possible to switch between SpreadCycle and StealthChop mode by simply switching CFG1 and CFG2.

CFG1 AND CFG2: SET MICROSTEP RESOLUTION FOR STEP INPUT				
CFG2, CFG1	Microsteps	Interpolation	Chopper Mode	
GND, GND	1 (Fullstep)	N	*SpreadCycle*	
GND, VCC_IO	2 (Halfstep)	N		
GND, open	2 (Halfstep)	Y, to 256 µsteps		
VCC_IO, GND	4 (Quarterstep)	N		
VCC_IO, VCC_IO	16 µsteps	N		
VCC_IO, open	4 (Quarterstep)	Y, to 256 µsteps		
open, GND	16 µsteps	Y, to 256 µsteps		
open, VCC_IO	4 (Quarterstep)	Y, to 256 µsteps	*StealthChop*	
open, open	16 µsteps	Y, to 256 µsteps		

Hint
Be sure to allow the motor to rest for at least 100 ms (assuming a minimum of 10 MHz f_{CLK}) before starting a motion using StealthChop. This will allow the current regulation to ramp up to the initial motor current.

CFG0, CFG4 and CFG5 are intended for chopper configuration. CFG0 is used to set the chopper off time. This setting also limits the maximum chopper frequency. For operation with StealthChop, this parameter is not used. In case of operation with StealthChop only, any CFG0 setting is OK.

CFG0: SETS CHOPPER OFF TIME (DURATION OF SLOW DECAY PHASE)		
CFG0	*TOFF* Setting	
GND	140 t_{CLK} (recommended, most universal choice)	*low setting*
VCC_IO	236 t_{CLK}	*medium setting*
open	332 t_{CLK}	*high setting*

CFG4: SETS CHOPPER HYSTERESIS (TUNING OF ZERO CROSSING PRECISION)	
CFG4	**Hysteresis Setting**
GND	5 (recommended most universal choice): low hysteresis with ≈4% of full scale current.
VCC_IO	9: medium setting with ≈5% of the full scale current at sense resistor.
open	13: high setting with ≈6% of full scale current at sense resistor.

CFG5 selects the comparator blank time. This time needs to safely cover the switching event and the duration of the ringing on the sense resistor. For most applications, a setting of 24 clock cycles is good. For higher capacitive loads, e.g. when filter networks are used, a setting 36 clock cycles will be required.

CFG5: SETS CHOPPER BLANK TIME (DURATION OF BLANKING OF SWITCHING SPIKE)		
CFG5	**Blank time (in number of clock cycles)**	
GND	16 (best performance for StealthChop)	*low setting*
VCC_IO	24 (recommended, most universal choice)	*medium setting*
open	36 (may be necessary with high capacitive loads on motor outputs)	*high setting*

EXAMPLE 1

It is desired to do slow motions in smooth and noiseless StealthChop mode. For quick motions, SpreadCycle is to be used. The controller can deliver 1/16 microstep step signals. Leave open CFG2 and drive CFG1 with a three state driver. Switch CFG1 to GND to operate in SpreadCycle, switch it to hi-Z (open) state for a motion in StealthChop. Be sure to switch during standstill only, because when switching from a fixed level to an open input, a different mode may be passed for a short time.

EXAMPLE 2
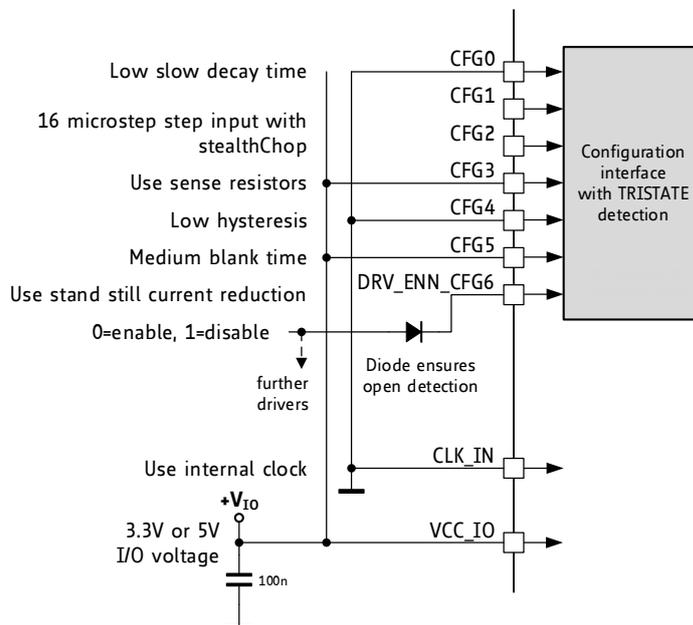
Figure 3.2 TMC2100 example configuration for StealthChop

Attention
Pin open detection will fail, when paralleling CFG pins of different ICs! Use one diode per IC, if one or multiple pins are switched between GND and open or between VCC_IO and open.
Tristate detection is sensitive to capacitive stray inherent with long interconnections- use a 100pF filter capacitor, or a diode near to the pin, if the open state shall be controlled via an external source.

4   Suggestions for Layout

The sample circuits show the connection of external components in different operation and supply modes.

4.1   Basic Hints for Power Supply

Use low ESR capacitors for filtering the power supply which are capable to cope with the current ripple. The current ripple often depends on the power supply and cable length. The VCC_IO voltage can be supplied from 5VOUT, or from an external source, e.g. a low drop 3.3V regulator. In order to minimize linear voltage regulator power dissipation of the internal 5V voltage regulator in applications where VM is high, a different (lower) supply voltage can be used for VSA, if available. For example, many applications provide a 12V supply in addition to a higher supply voltage, like 24V or 36V. Using the 12V supply for VSA will reduce the power dissipation of the internal 5V regulator to about 37% resp. 23% of the dissipation caused by supply with the full motor voltage.

> *Basic Layout Hints*
> Place sense resistors and all filter capacitors as close as possible to the related IC pins. Use a solid common GND for all GND connections, also for sense resistor GND. Connect 5VOUT filtering capacitor directly to 5VOUT and GNDA pin. See layout hints for more details. Low ESR electrolytic capacitors are recommended for VS filtering.

> *Attention*
> In case VSA is supplied by a different voltage source, make sure that VSA does not exceed VS by more than one diode drop upon power up or power down.

4.2   Reduced Number of Components
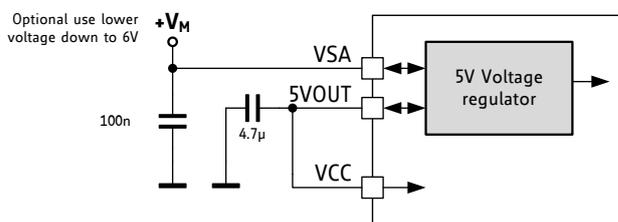
Figure 4.1 Reduced number of filtering components

The standard application circuit uses RC filtering to de-couple the output of the internal linear regulator from high frequency ripple caused by digital circuitry supplied by the VCC input. For cost sensitive applications, the RC-filtering on VCC can be eliminated. This leads to more noise on 5VOUT caused by operation of the charge pump and the internal digital circuitry. There is a slight impact on microstep vibration and chopper noise performance.

4.3   Internal Current Sensing

For cost critical or space limited applications, it may be desired to eliminate the sense resistors. The TMC2100 allows using the resistance of the internal MOSFETs as a sense resistor. Further, this slightly reduces power dissipation, because the effective resistance of the driver bridge is reduced. In this application, a reference current set by a tiny external resistor programs the output current. For calculation of the reference resistor, refer chapter 9.
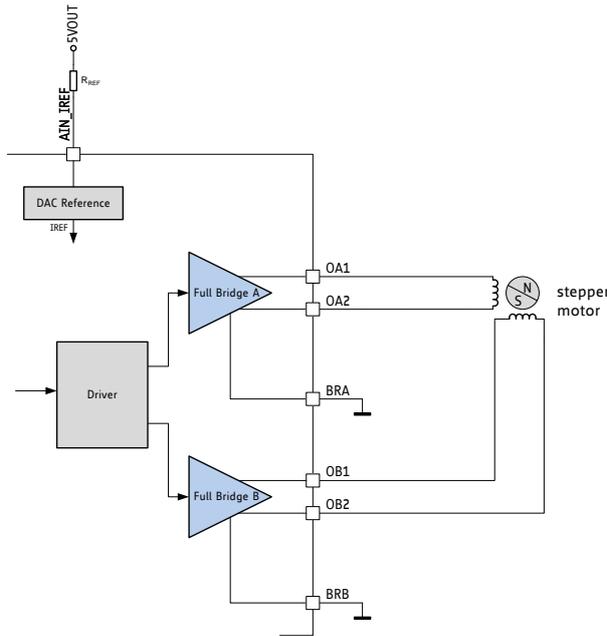
Figure 4.2 RDSon based sensing eliminates high current sense resistors

4.4   External 5V Power Supply

When an external 5V power supply is available, the power dissipation caused by the internal linear regulator can be eliminated. This especially is beneficial in high voltage applications, and when thermal conditions are critical. There are two options for using an external 5V source: either the external 5V source is used to support the digital supply of the driver by supplying the VCC pin, or the complete internal voltage regulator becomes bridged and is replaced by the external supply voltage.

4.4.1   Support for the VCC Supply

This scheme uses an external supply for all digital circuitry within the driver (Figure 4.3). As the digital circuitry makes up for most of the power dissipation, this way the internal 5V regulator sees only low remaining load. The precisely regulated voltage of the internal regulator is still used as the reference for the motor current regulation as well as for supplying internal analog circuitry.

When cutting VCC from 5VOUT, make sure that the VCC supply comes up before or synchronously with the 5VOUT supply to ensure a correct power up reset of the internal logic. A simple schematic uses two diodes forming an OR of the internal and the external power supplies for VCC. In order to prevent the chip from drawing part of the power from its internal regulator, a low drop 1A Schottky diode is used for the external 5V supply path, while a silicon diode is used for the 5VOUT path.
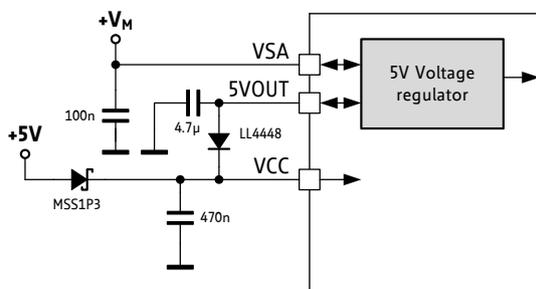
VCC supplied from external 5V. 5V or 3.3V IO voltage.

Figure 4.3 Using an external 5V supply for digital circuitry of driver

4.4.2 Internal Regulator Bridged

In case a clean external 5 V supply is available, it can be used for supply of analog and digital part (Figure 4.4). The circuit will benefit from a well-regulated supply, e.g. when using a +/-1% regulator. A precise supply guarantees increased motor current precision, because the voltage on 5VOUT directly is used as reference for all internal units of the driver, especially for motor current control. For best performance, the power supply should have low ripple to give a precise and stable supply at 5VOUT pin with remaining ripple well below 5 mV. Some switching regulators have a higher remaining ripple, or different loads on the supply may cause lower frequency ripple. In this case, increase capacity attached to 5VOUT. In case the external supply voltage has poor stability or low frequency ripple, this would affect the precision of the motor current regulation as well as add chopper noise.
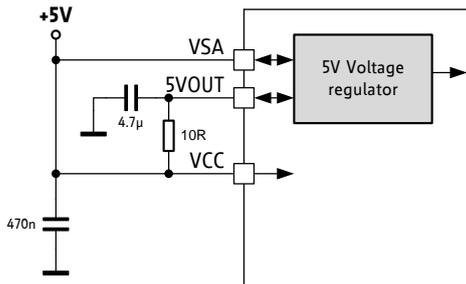
Figure 4.4 Using an external 5V supply to bypass internal regulator

4.5 5V Only Supply
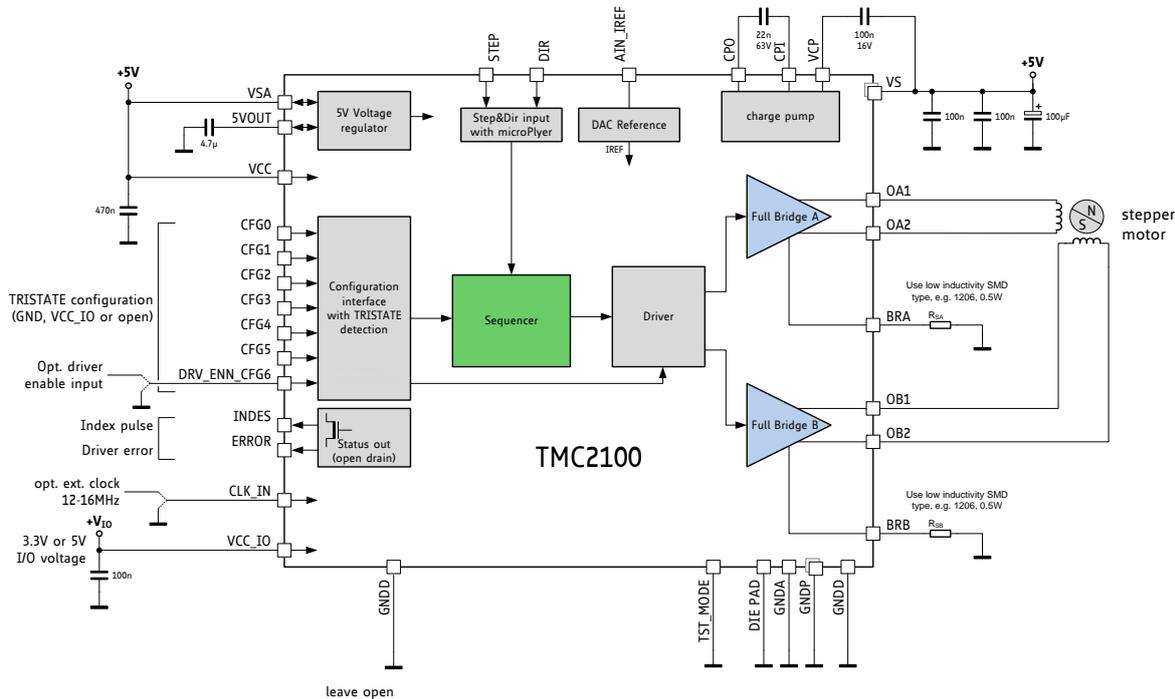
Figure 4.5 5V only operation

While the standard application circuit is limited to roughly 5.5 V lower supply voltage, a 5 V only application lets the IC run from a normal 5 V +/-5% supply. In this application, linear regulator drop must be minimized. Therefore, the major 5 V load is removed by supplying VCC directly from the external supply. In order to keep supply ripple away from the analog voltage reference, 5VOUT should have an own filtering capacity and the 5VOUT pin does not become bridged to the 5V supply.

4.6   High Motor Current

When operating at a high motor current, the driver power dissipation due to MOSFET switch on-resistance significantly heats up the driver. This power dissipation will significantly heat up the PCB cooling infrastructure, if operated at an increased duty cycle. This in turn leads to a further increase of driver temperature. An increase of temperature by about 100 °C increases MOSFET resistance by roughly 50%. This is a typical behavior of MOSFET switches. Therefore, under high duty cycle, high load conditions, thermal characteristics have to be carefully taken into account, especially when increased environment temperatures are to be supported. Refer the thermal characteristics and the layout hints for more information. As a thumb rule, thermal properties of the PCB design become critical for the tiny QFN-36 package at or above about 1000 mA RMS motor current for increased periods of time. Keep in mind that resistive power dissipation raises with the square of the motor current. On the other hand, this means that a small reduction of motor current significantly saves heat dissipation and energy.

An effect which might be perceived at medium motor velocities and motor sine wave peak currents above roughly 1.2 A peak is slight sine distortion of the current wave when using SpreadCycle. It results from an increasing negative impact of parasitic internal diode conduction, which in turn negatively influences the duration of the fast decay cycle of the SpreadCycle chopper. This is, because the current measurement does not see the full coil current during this phase of the sine wave, because an increasing part of the current flows directly from the power MOSFETs' drain to GND and does not flow through the sense resistor. This effect with most motors does not negatively influence the smoothness of operation, as it does not impact the critical current zero transition. It does not occur with StealthChop.

4.6.1   Reduce Linear Regulator Power Dissipation

When operating at high supply voltages, as a first step the power dissipation of the integrated 5V linear regulator can be reduced, e.g. by using an external 5V source for supply. This will reduce overall heating. It is advised to reduce motor stand still current in order to decrease overall power dissipation. If applicable, also use coolStep. A decreased clock frequency will reduce power dissipation of the internal logic. Further a decreased clock frequency also reduces power dissipation.

4.6.2   Operation near to / above 2A Peak Current

The driver can deliver up to 2.5 A motor peak current. Considering thermal characteristics, this only is possible in duty cycle limited operation. When a peak current up to 2.5 A is to be driven, the driver chip temperature is to be kept at a maximum of 105 °C. Linearly derate the design peak temperature from 125 °C to 105 °C in the range 2 A to 2.5 A output current (see Figure 4.6). Exceeding this may lead to triggering the short circuit detection.
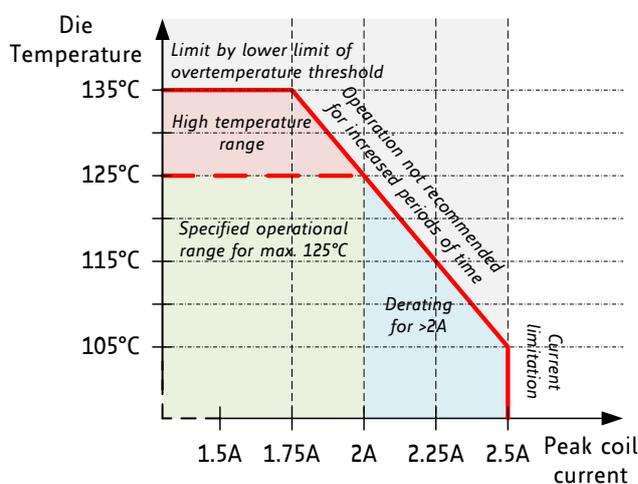
Figure 4.6 Derating of maximum sine wave peak current at increased die temperature

4.7 Driver Protection and EME Circuitry

Some applications have to cope with ESD events caused by motor operation or external influence. Despite ESD circuitry within the driver chips, ESD events occurring during operation can cause a reset or even a destruction of the motor driver, depending on their energy. Especially plastic housings and belt drive systems tend to cause ESD events of several kV. It is best practice to avoid ESD events by attaching all conductive parts, especially the motors themselves to PCB ground, or to apply electrically conductive plastic parts. In addition, the driver can be protected up to a certain degree against ESD events or live plugging / pulling the motor, which also causes high voltages and high currents into the motor connector terminals. A simple scheme uses capacitors at the driver outputs to reduce the dV/dt caused by ESD events. Larger capacitors will bring more benefit concerning ESD suppression, but cause additional current flow in each chopper cycle, and thus increase driver power dissipation, especially at high supply voltages. The values shown are example values – they might be varied between 100pF and 1nF. The capacitors also dampen high frequency noise injected from digital parts of the application PCB circuitry and thus reduce electromagnetic emission. A more elaborate scheme uses LC filters to de-couple the driver outputs from the motor connector. Varistors in between of the coil terminals eliminate coil overvoltage caused by live plugging. Optionally protect all outputs by a varistor against ESD voltage.
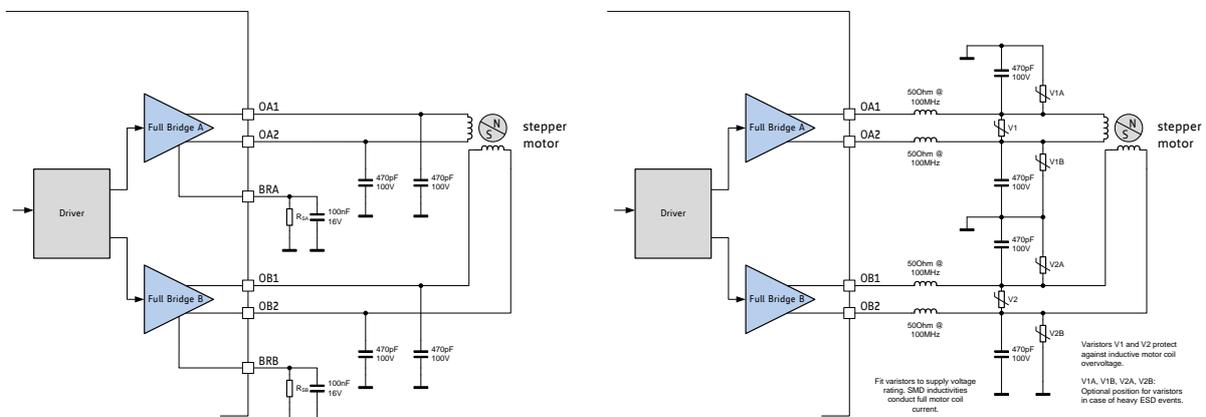
Figure 4.7 Simple ESD enhancement and more elaborate motor output protection

5 StealthChop™

StealthChop is an extremely quiet mode of operation for stepper motors. It is based on a voltage mode PWM. In case of standstill and at low velocities, the motor is absolutely noiseless. Thus, StealthChop operated stepper motor applications are very suitable for indoor or home use. The motor operates absolutely free of vibration at low velocities. With StealthChop, the motor current is applied by driving a certain effective voltage into the coil, using a voltage mode PWM. There are no more configurations required except for the regulation of the PWM voltage to yield the motor target current. Consider SpreadCycle for high velocity drives.
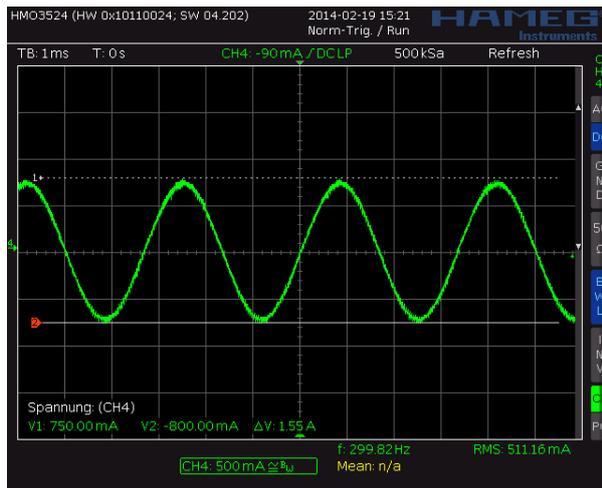
Figure 5.1 Motor coil sine wave current with StealthChop (measured with current probe)

5.1 Current Regulation

In order to match the motor current to a certain level, the voltage mode PWM voltage must be scaled depending on the actual motor velocity. Several additional factors influence the required voltage level to drive the motor at the target current: the motor resistance, its back EMF (i.e. directly proportional to its velocity) as well as actual level of the supply voltage. For the ease of use, the TMC2100 uses an automatic mode for current regulation which considers current feedback. The PWM frequency is internally divided from the clock frequency.

> A higher PWM frequency leads to increased dynamic power dissipation, but it may bring a benefit for higher motor velocity.

PWM FREQUENCY FOR STEALTHCHOP	
Clock frequency f_{CLK}	**f_{PWM}=2/683 f_{CLK}**
18MHz	52.7kHz
16MHz	46.8kHz
(internal)	~38kHz
12MHz	35.1kHz
10MHz	29.3kHz
8MHz	23.4kHz

Table 5.1 PWM frequency – green: recommended

5.2 Automatic Scaling

In StealthChop voltage PWM mode, the internal autoscaling function regulates the motor current to the desired current setting. The driver measures the motor current during the chopper on time and uses a proportional regulator in order match the motor current to the target current. The quality of the regulation can be examined when monitoring the motor coil current at different velocities and

during fastest applicable acceleration. Just as in the acceleration phase, during a deceleration phase the voltage PWM amplitude must be adapted in order to keep the motor coil current constant.
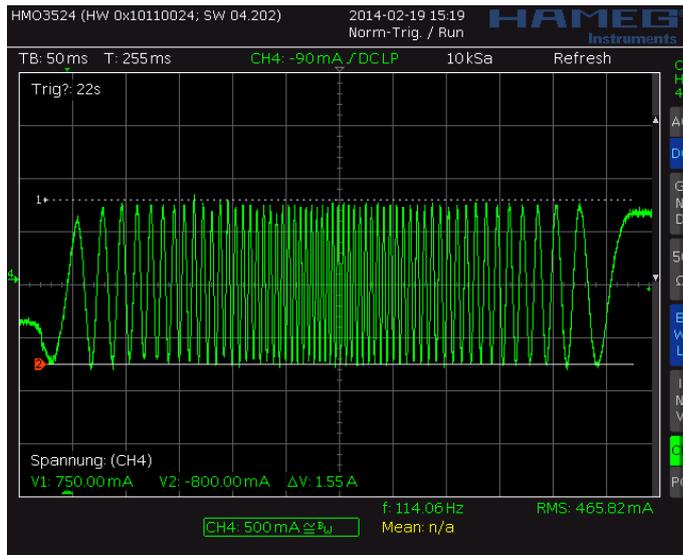
Figure 5.2 Scope shot: current can follow on acceleration phase

Current vs. velocity with acceleration in a good range
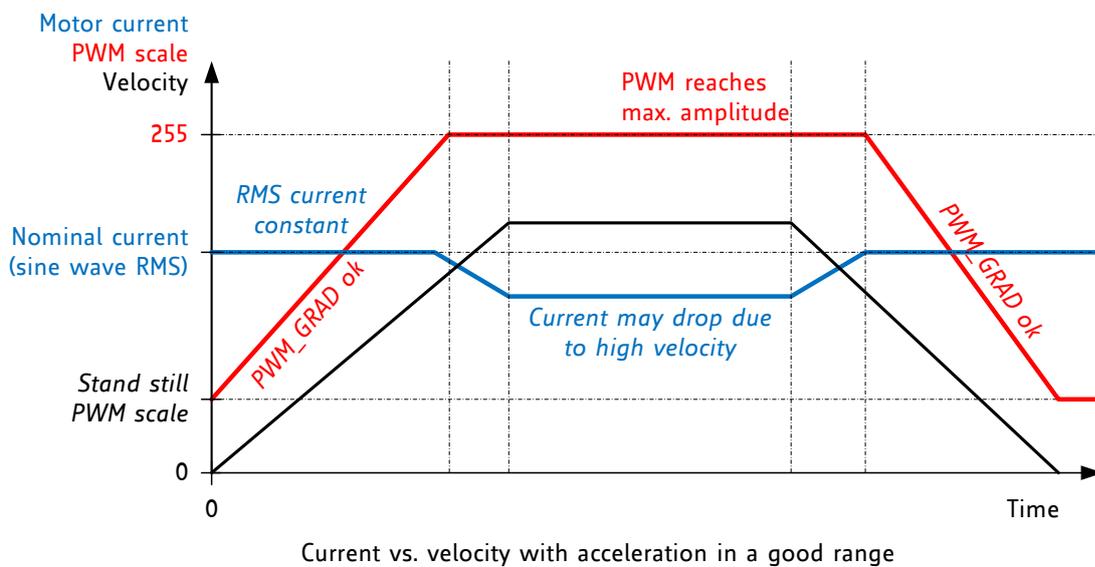
Figure 5.3 Current vs. velocity diagram

> Be sure to use a symmetrical sense resistor layout and sense resistor traces of identical length and well matching sense resistors for best performance.
>
> The auto scaling function only starts up regulation during motor standstill. Do not start motion directly after enabling StealthChop. Wait until the current regulation has reached a stable state before starting a motion. Failure to do so will result in zero motor current!
>
> In case the automatic scaling regulation is instable at your desired motion velocity, try modifying the clock frequency. Also adapt the blank time (CFG5) and motor current for best result.

5.2.1 Lower Current Limit

The StealthChop current regulator imposes a lower limit for motor current regulation. As the coil current can be measured in the shunt resistor during chopper on phase only, a minimum chopper duty cycle allowing coil current regulation is given by the blank time as set by *TBL* and by the chopper frequency. Therefore, the motor specific minimum coil current in StealthChop autoscaling

mode rises with the supply voltage. A lower blanking time allows a lower current limit. The run current needs to be kept above the lower limit: In case the PWM scale drops to a too low value, e.g. because AIN pin scaling was too low, the regulator may not be able to recover. The regulator will recover once the motor is in standstill. The lower motor coil current limit can be calculated from motor parameters and chopper settings:

$$I_{Lower\ Limit} = t_{BLANK} * f_{PWM} * \frac{V_M}{R_{COIL}}$$

With V_M the motor supply voltage and R_{COIL} the motor coil resistance.
$I_{Lower\ Limit}$ can be treated as a thumb value for the minimum possible motor current setting.

EXAMPLE:

A motor has a coil resistance of 5Ω, the supply voltage is 24V. t_{BLANK} setting is 24 clock cycles:

$$I_{Lower\ Limit} = 24\ t_{CLK} * \frac{2}{683\ t_{CLK}} * \frac{24V}{5\Omega} = \frac{2*24}{683} * \frac{24V}{5\Omega} = 337mA$$

For *pwm_autoscale* mode, a lower coil current limit applies. This limit can be calculated or measured using a current probe. Keep the motor run-current setting well above this lower current limit.

5.3 Acceleration

The automatic current regulation compensates for the change of back-EMF at different velocities (see Figure 5.2 and Figure 5.3). It measures the actual current with each fullstep and subsequently does a limited correction of the PWM voltage. Therefore, at high acceleration or deceleration, the internal regulation might not react quickly enough to stabilize the motor current within a range near the target current. Use a current probe and check the motor current during (quick) acceleration. In case the current regulation cannot follow (see Figure 5.4), motor current will sink in acceleration phases, and thus lead to reduced motor torque. During a deceleration phase it will rise for a short time. If the current deviates too much, the motor cannot bring the required torque during the acceleration phase.

In case motor current drops significantly during acceleration phases with StealthChop there are several ways to improve current regulation:

- Reduce acceleration
- Switch from hold current to run current in time before starting the motion
- Increase driver supply voltage (at double voltage, the reaction speed is also doubled)
- Use motor with higher current coil winding (back-EMF sinks proportionally)
- Increase driver clock frequency (this will speed up regulation when accelerating from standstill current reduction)
- Switch configuration from StealthChop to SpreadCycle before starting a high velocity motion
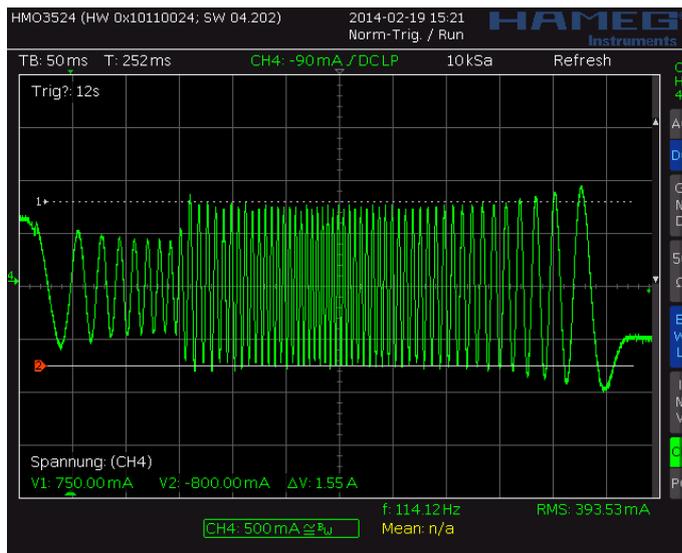
Figure 5.4 Current regulation cannot follow during high acceleration phase

> *Hint*
> Operate the motor within your application when exploring StealthChop. Motor performance often is better with a mechanical load, because it prevents the motor from stalling due mechanical oscillations which can occur without load.

5.4 Switching between StealthChop and SpreadCycle

It is principally possible to combine StealthChop and SpreadCycle by toggling between two configurations using the related CFG pins. But care must be taken to avoid operating in a wrong microstepping mode. As the tristate detection logic needs a number of cycles to detect transition to or from an open pin, the switching should only be done during standstill. Allow 3072 t_{CLK} for detection of the changed mode selection, before driving a new step. With internal clock, a 3ms delay will ensure proper transition to the new mode, before the next step is done.

When enabling the StealthChop mode the first time using automatic current regulation, the motor must be at stand still in order to allow a proper current regulation. When the drive switches to a different chopper mode at a higher velocity, StealthChop logic stores the last current regulation setting until the motor returns to a lower velocity again. This way, the regulation has a known starting point when returning to a lower velocity, where StealthChop becomes re-enabled. Therefore, neither the velocity threshold nor the supply voltage must be considerably changed during the phase while the chopper is switched to a different mode, because otherwise the motor might lose steps or the instantaneous current might be too high or too low.

> *Attention*
> A motor stall or a sudden change in the motor velocity may lead to the driver detecting a short circuit, as the current can exceed the upper limit in these situations. In these situations, the automatic current regulation may also reach a state of low current from which it cannot recover.
> Stop motion, disable and re-enable the driver (using the ENN pin) and restart the motor from zero velocity to recover from this situation.

> *Hint*
> Start the motor from standstill when switching on StealthChop the first time and keep it stopped for at least 128 chopper periods to allow StealthChop to do initial standstill current control.

6   SpreadCycle

While StealthChop is a voltage mode PWM controlled chopper, SpreadCycle is a cycle-by-cycle current control. Therefore, it can react extremely fast to changes in motor velocity or motor load. The currents through both motor coils are controlled using choppers. The choppers work independently of each other. In Figure 6.1 the different chopper phases are shown.

On Phase:
current flows in
direction of target
current

Fast Decay Phase:
current flows in
opposite direction
of target current

Slow Decay Phase:
current re-circulation
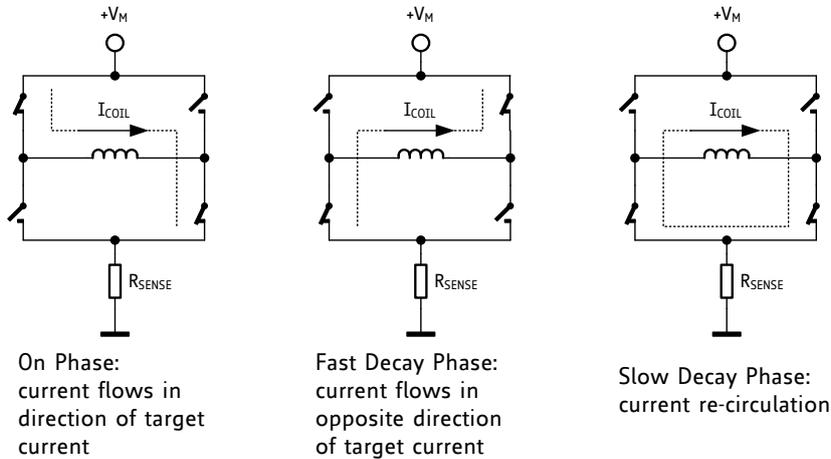
Figure 6.1 Chopper phases

Although the current could be regulated using only on phases and fast decay phases, insertion of the slow decay phase is important to reduce electrical losses and current ripple in the motor. The duration of the slow decay phase is specified in a control parameter and sets an upper limit on the chopper frequency. The current comparator can measure coil current during phases when the current flows through the sense resistor, but not during the slow decay phase, so the slow decay phase is terminated by a timer. The on phase is terminated by the comparator when the current through the coil reaches the target current. The fast decay phase may be terminated by either the comparator or another timer.

When the coil current is switched, spikes at the sense resistors occur due to charging and discharging parasitic capacitances. During this time, typically one or two microseconds, the current cannot be measured. Blanking is the time when the input to the comparator is masked to block these spikes.

The SpreadCycle mode cycles through four phases: on, slow decay, fast decay, and a second slow decay.

The chopper frequency is an important parameter for a chopped motor driver. A too low frequency might generate audible noise. A higher frequency reduces current ripple in the motor, but with a too high frequency magnetic losses may rise. Also power dissipation in the driver rises with increasing frequency due to the increased influence of switching slopes causing dynamic dissipation. Therefore, a compromise needs to be found. Most motors are optimally working in a frequency range of 16 kHz to 30 kHz. The chopper frequency is influenced by a number of parameter settings as well as by the motor inductivity and supply voltage.

> *Hint*
> A chopper frequency in the range of 16 kHz to 30 kHz gives a good result for most motors when using SpreadCycle. A higher frequency leads to increased switching losses.

Please refer to chapter 3.1 for more information about CFG0 and CFG4 (chopper off time and chopper hysteresis).

6.1 SpreadCycle Chopper

The patented SpreadCycle chopper algorithm is a precise and simple to use chopper mode which automatically determines the optimum length for the fast-decay phase. The SpreadCycle will provide superior microstepping quality even with default settings. Several parameters are available to optimize the chopper to the application.

Each chopper cycle is comprised of an on phase, a slow decay phase, a fast decay phase and a second slow decay phase (see Figure 6.3). The two slow decay phases and the two blank times per chopper cycle put an upper limit to the chopper frequency. The slow decay phases typically make up for about 50%-75% of the chopper cycle in standstill and are important for low motor and driver power dissipation.

EXAMPLE

At 16MHz clock frequency a low t_{OFF} setting (140 t_{CLK}) sets $t_{OFF} = 140 * \frac{1}{16MHz} = 8.75\mu s$. Each chopper cycle then uses 2 * 8.75μs = 17.2 μs of slow decay time.

The hysteresis setting forces the driver to introduce a minimum amount of current ripple into the motor coils. The current ripple must be higher than the current ripple which is caused by resistive losses in the motor in order to give best microstepping results. This will allow the chopper to precisely regulate the current both for rising and for falling target current. The time required to introduce the current ripple into the motor coil also reduces the chopper frequency. Therefore, a higher hysteresis setting will lead to a lower chopper frequency. The motor inductance limits the ability of the chopper to follow a changing motor current. Further the duration of the on phase and the fast decay must be longer than the blanking time, because the current comparator is disabled during blanking.

It is easy to find the best setting by starting with the lowest hysteresis setting (CFG4=GND). Use a higher setting in case the motor does not run smoothly at low velocity settings. This can best be checked when measuring the motor current either with a current probe or by probing the sense resistor voltages (see Figure 6.2). Checking the sine wave shape near zero transition will show a small ledge between both half waves in case the hysteresis setting is too small. At medium velocities (i.e. 100 to 400 fullsteps per second), a too low hysteresis setting will lead to increased humming and vibration of the motor.
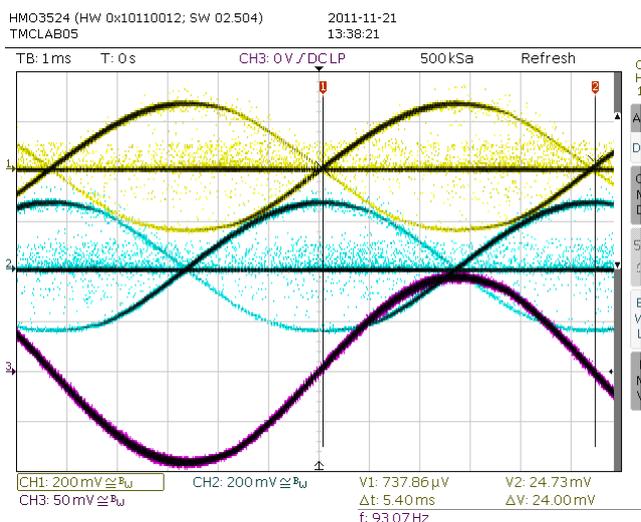
Figure 6.2 No ledges in current wave with sufficient hysteresis (magenta: current A, yellow & blue: sense resistor voltages A and B)

A too high hysteresis setting will lead to reduced chopper frequency and increased chopper noise but will not yield any benefit for the wave shape.

As experiments show, the setting is quite independent of the motor, because higher current motors typically also have a lower coil resistance. Therefore, choosing the low default value for the hysteresis normally fits most applications.
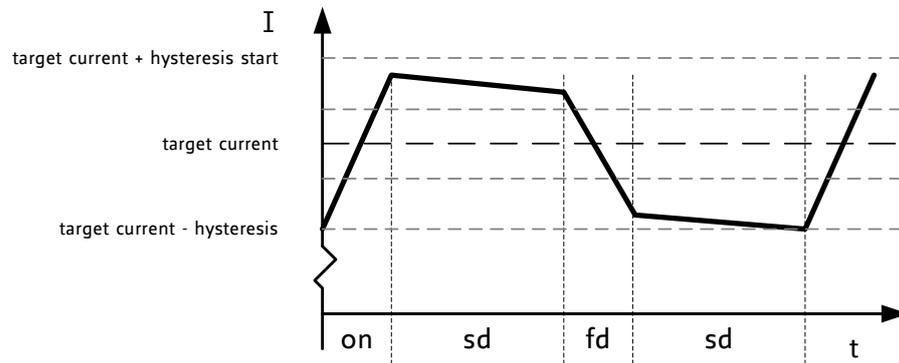
Figure 6.3 SpreadCycle chopper scheme showing coil current during a chopper cycle

7 Selecting Sense Resistors

Set the desired maximum motor current by selecting an appropriate value for the sense resistor. The following table shows the RMS current values which can be reached using standard resistors and motor types fitting without additional motor current scaling.

CHOICE OF R_{SENSE} AND RESULTING MAX. MOTOR CURRENT		
R_{SENSE} [Ω]	RMS current [A] AIN=2.5V (or open),	Fitting motor type (examples)
1.00	0.23	
0.82	0.27	
0.75	0.30	300mA motor
0.68	0.33	400mA motor
0.50	0.44	
470m	0.47	500mA motor
390m	0.56	600mA motor
330m	0.66	700mA motor
270m	0.79	800mA motor
220m	0.96	1A motor
180m	1.15	1.2A motor
150m	1.35	
120m	1.64*)	
100m	1.92*)	1.5A motor

*) Value exceeds upper current rating, scaling down required, e.g. by reduced AIN.

Sense resistors should be carefully selected. The full motor current flows through the sense resistors. Due to chopper operation the sense resistors see pulsed current from the MOSFET bridges. Therefore, a low-inductance type such as film or composition resistors is required to prevent voltage spikes causing ringing on the sense voltage inputs leading to unstable measurement results. Also, a low-inductance, low-resistance PCB layout is essential. Any common GND path for the two sense resistors must be avoided, because this would lead to coupling between the two current sense signals. A massive ground plane is best. Please also refer to layout considerations in chapter 16.

The sense resistor needs to be able to conduct the peak motor coil current in motor standstill conditions, unless standby power is reduced. Under normal conditions, the sense resistor conducts less than the coil RMS current, because no current flows through the sense resistor during the slow decay phases. A 0.5W type is sufficient for most applications up to 1.2A RMS current.

The peak sense resistor power dissipation is:

$$P_{RSMAX} = I_{COIL}{}^2 * R_{SENSE}$$

> *Attention*
> Be sure to use a symmetrical sense resistor layout and short and straight sense resistor traces of identical length. Well matching sense resistors ensure best performance.
> A compact layout with massive ground plane is best to avoid parasitic resistance effects.

8   Motor Current Control

The basic motor current is set by the resistance of the sense resistors. Several possibilities allow scaling down motor current, e.g. to adapt for different motors, or to reduce motor current in standstill or low load situations.

Three modes of current setting can be chosen using the CFG3 pin:

CFG3: Sets Mode of Current Setting	
CFG3	**Current Setting**
GND	Internal reference voltage. Current scale set by sense resistors, only.
VCC_IO	Internal sense resistors. This setting gives best results when combined with StealthChop voltage PWM chopper. Tie BRA and BRB directly to GND. See chapter 9 for details.
open	External reference voltage on pin AIN. Current scale set by sense resistors and scaled by AIN. This allows fine tuning of current setting using a simple voltage divider.

Select the sense resistor to deliver enough current for the motor at full current scale (VREF=2.5V).

RMS RUN CURRENT CALCULATION:

$$I_{RMS} = \frac{V_{FS}}{R_{SENSE}+20m\Omega} * \frac{1}{\sqrt{2}}$$

STANDBY HOLD CURRENT CALCULATION:

$$I_{RMS} = \frac{12}{32} * \frac{V_{FS}}{R_{SENSE}+20m\Omega} * \frac{1}{\sqrt{2}}$$

with V_{FS} = full scale voltage (see V_{SRT})

CURRENT REDUCTION BY ANALOG SCALING:

When analog scaling of V_{FS} is enabled, the resulting voltage V_{FS}' is calculated by:

$$V'_{FS} = V_{FS} * \frac{V_{AIN}}{2.5V}$$

with V_{AIN} the voltage on pin AIN_IREF in the range 0V to V_{5VOUT}/2

> For best precision of current setting, it is advised to measure and fine tune the current in the application.

8.1   Analog Current Scaling AIN

When a high flexibility of the output current scaling is desired, the analog input of the driver can be enabled for current control, rather than choosing a different set of sense resistors. This way, a simple voltage divider can be used for the adaptation of a board to different motors. Therefore, leave the CFG3 pin open.

AIN SCALES THE MOTOR CURRENT

The TMC2100 provides an internal reference voltage for current control, directly derived from the 5VOUT supply output. Alternatively, an external reference voltage can be used. This reference voltage becomes scaled down for the chopper comparators. The chopper comparators compare the voltages on BRA and BRB to the scaled reference voltage for current regulation. If analogue scaling is enabled (CFG3 open), the external voltage on AIN is amplified and filtered and becomes used as reference voltage. A voltage of 2.5V (or any voltage between 2.5V and 5V) gives the same current scaling as the internal reference voltage. A voltage between 0V and 2.5V linearly scales the current between 0 and the current scaling defined by the sense resistor setting. It is not advised to work with reference

voltages below about 0.5V to 1V, because analog noise caused by digital circuitry has an increased impact on the chopper precision at low AIN voltages. For best precision, choose the sense resistors in a way that the desired maximum current is reached with AIN in the range 2V to 2.4V. Be sure to optimize the chopper settings for the normal run current of the motor.

DRIVING AIN

The easiest way to provide a voltage to AIN is to use a voltage divider from a stable supply voltage or a microcontroller's DAC output. A PWM signal can also be used for current control. The PWM becomes transformed to an analog voltage using an additional R/C low-pass at the AIN pin. The PWM duty cycle controls the analog voltage. Choose the R and C values to form a low pass with a corner frequency of several milliseconds while using PWM frequencies well above 10 kHz. AIN additionally provides an internal low-pass filter with 3.5kHz bandwidth. The integration of an NTC into the voltage divider feeding AIN allows the realization of temperature dependent motor current scaling. When a precise reference voltage is available (e.g. from TL431A), the precision of the motor current regulation can be improved when compared to the internal voltage reference.

> *Hint*
> Using a low reference voltage (e.g. below 1V), for adaptation of a high current driver to a low current motor will lead to reduced analog performance. Adapting the sense resistors to fit the desired motor current gives a better result.
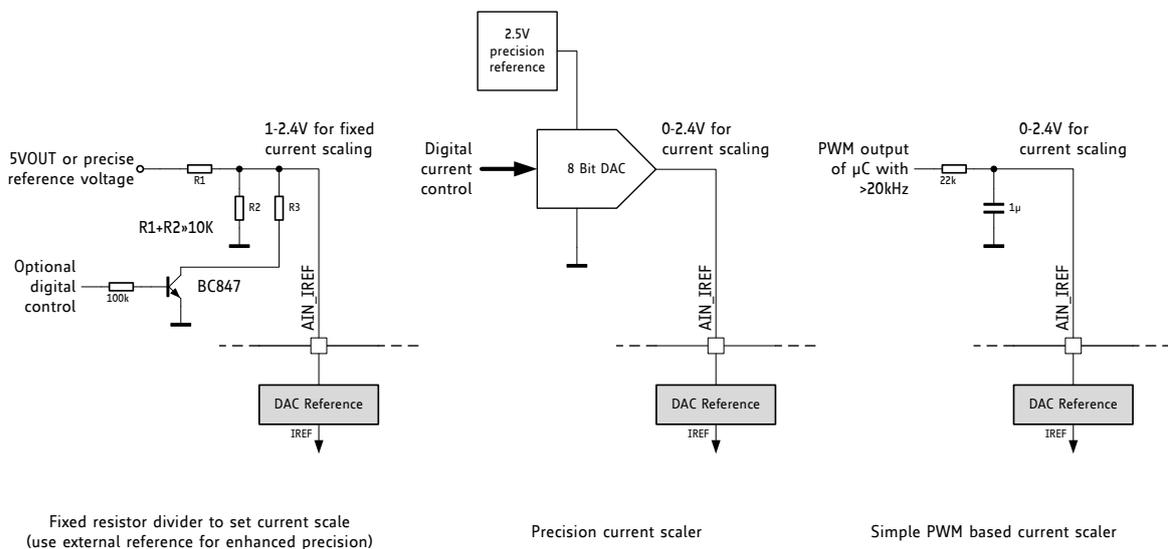
Figure 8.1 Scaling the motor current using the analog input

9   Internal Sense Resistors

The TMC2100 provides the option to eliminate external sense resistors. In this mode the external sense resistors become omitted (shorted) and the internal on-resistance of the power MOSFETs is used for current measurement (see Figure 4.2). As MOSFETs are both, temperature dependent and subject to production stray, a tiny external resistor connected from +5VOUT to AIN/IREF provides a precise absolute current reference. This resistor converts the 5V voltage into a reference current. Be sure to directly attach BRA and BRB pins to GND in this mode near the IC package. The mode is enabled by tying CFG3 to VCCIO.

COMPARING INTERNAL SENSE RESISTORS VS. SENSE RESISTORS		
Item	Internal Sense Resistors	External Sense Resistors
Cost	(+) Save cost for sense resistors	
Current precision	Slightly reduced	(+) Good
Current Range Recommended	200mA RMS to 1.2A RMS	50mA to 1.4A RMS
Recommended chopper	StealthChop, SpreadCycle shows slightly reduced performance at >1A	StealthChop or SpreadCycle

While the RDSon based measurements bring benefits concerning cost and size of the driver, it gives slightly less precise coil current regulation when compared to external sense resistors. The internal sense resistors have a certain temperature dependence, which is automatically compensated by the driver IC. However, for high current motors, a temperature gradient between the ICs internal sense resistors and the compensation circuit will lead to an initial current overshoot of some 10% during driver IC heat up. While this phenomenon shows for roughly a second, it might even be beneficial to enable increased torque during initial motor acceleration.

PRINCIPLE OF OPERATION

A reference current into the VREF pin is used as reference for the motor current. In order to realize a certain current, a single resistor (R_{REF}) can be connected between 5VOUT and AIN (pls. refer the table for the choice of the resistor). AIN input resistance is about 1kOhm. The resulting current into AIN is amplified 3000 times. Thus, a current of 0.5mA yields a motor current of 1.5A peak. For calculation of the reference resistor, the internal resistance of AIN needs to be considered additionally. When using reference currents above 0.5 mA resulting in higher theoretical current settings of up to 2 A, the resulting current decreases linearly when chip temperature exceeds a certain maximum temperature. For a 2 A setting it decreases from 2 A at up to 100°C down to about 1.5 A at 150°C.

CHOICE OF R_{REF} FOR OPERATION WITHOUT SENSE RESISTORS		
R_{REF} [Ω]	Peak current [A]	RMS current [A]
6k8	1.92	1.35
7k5	1.76	1.24
8k2	1.63	1.15
9k1	1.49	1.05
10k	1.36	0.96
12k	1.15	0.81
15k	0.94	0.66
18k	0.79	0.55
22k	0.65	0.45
24k	0.60	0.42
27k	0.54	0.38

In RDSon measurement mode, connect the BRA and BRB pins to GND using the shortest possible path (i.e. lowest possible PCB resistance). RDSon based measurement gives best results when combined

with StealthChop. When using SpreadCycle with RDSon based current measurement, slightly asymmetric current measurement for positive currents (on phase) and negative currents (fast decay phase) may result in chopper noise. This especially occurs at high die temperature and increased motor current.

Note
The absolute current levels achieved with RDSon based current sensing may depend on PCB layout exactly like with external sense resistors, because trace resistance on BR pins will add to the effective sense resistance. Therefore we recommend to measure and calibrate the current setting within the application.

Thumb rule
RDSon based current sensing works best for motors with up to 1 A RMS current. The best results are yielded with StealthChop operation in combination with RDSon based current sensing.
For most precise current control and best results with SpreadCycle, it is recommended to use external 1% sense resistors rather than RDSon based current control.

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10 Driver Diagnostic and Protection

The TMC2100 drivers supply a set of diagnostic and protection capabilities, like short to GND protection and overtemperature detection and protection.

10.1 Temperature Measurement

The TMC2100 driver integrates a temperature sensor for protection against excess heat. In case the temperature reaches 150°C the TMC2100 reacts with automatic switching off. If the chip cools down afterwards and its temperature reaches 120°C, it recovers automatically and starts working.

Heat is mainly generated by the motor driver stages and the on-chip voltage regulator. The central temperature detector can detect heat accumulation on the chip, i.e. due to missing convection cooling or rising environment temperature. If continuous operation in hot environments is necessary, a more precise processor based temperature measurement should be used to realize application specific overtemperature detection. The thermal shutdown is just an emergency measure and temperature rising to the shutdown level should be prevented by design.

> *Attention*
> Overtemperature protection cannot in all cases avoid thermal destruction of the IC. In case the rated motor current is exceed, excess heat generation can quickly heat up the driver before the overtemperature sensor can react. This is due to a delay in heat conduction over the IC die.

> After triggering the overtemperature sensor, the driver remains switched off until the system temperature falls below 120°C to avoid continuous heating to the shutdown level.

10.2 Short to GND Protection

The TMC2100 power stages are protected against a short circuit condition by an additional measurement of the current flowing through the high-side MOSFETs. This is important, as most short circuit conditions result from a motor cable insulation defect, e.g. when touching the conducting parts connected to the system ground. The short detection is protected against spurious triggering, e.g. by ESD discharges, by retrying three times before switching off the motor.

> Once a short condition is safely detected, the corresponding driver bridge (A or B) becomes switched off and the error becomes indicated at the diagnostic ERROR output. In order to restart the motor, disable and re-enable the driver. Note, that short protection cannot protect the system and the power stages for all possible short events, as a short event is rather undefined and a complex network of external components may be involved. Therefore, short circuits should basically be avoided.

10.3 Emergency Stop

The driver provides a negative active enable pin ENN to safely switch off all power MOSFETs. This allows putting the motor into freewheeling. Further, it is a safe hardware function whenever an emergency stop not coupled to software is required.

10.4 Diagnostic Output

The driver ERROR pin becomes driven active low, whenever a driver error results in switching off the power stage. Thus, it indicates a potential step loss. An overtemperature condition becomes cleared automatically after cooling down below the threshold temperature. A short detection error can be cleared by switching off / on the driver using the ENN pin.
With low resistive motors operated in StealthChop, a short detection also can result from overcurrent conditions caused by hard motor deceleration or motor blocking or stop without acceleration ramp.
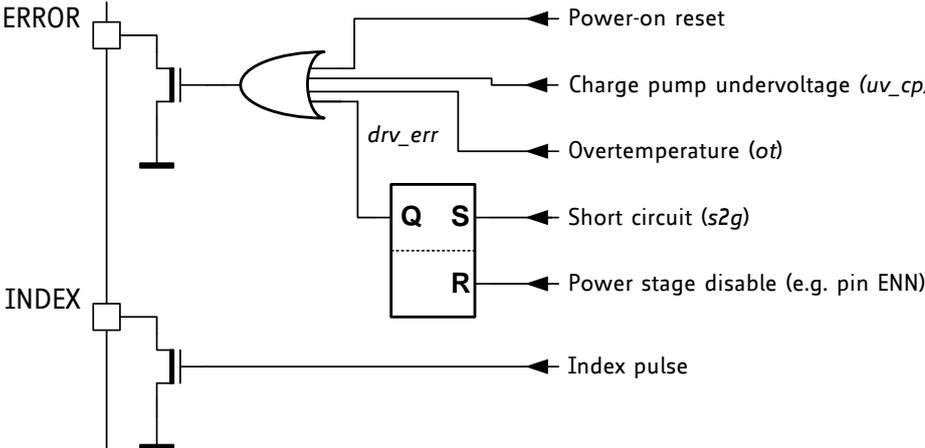
Figure 10.1 Error and Index output

11 STEP/DIR Interface

The STEP and DIR inputs provide a simple, standard interface compatible with many existing motion controllers. The MicroPlyer STEP pulse interpolator brings the smooth motor operation of high-resolution microstepping to applications originally designed for coarser stepping.

11.1 Timing

Figure 11.2 shows the timing parameters for the STEP and DIR signals, and the table below gives their specifications. Only rising edges are active. STEP and DIR are sampled and synchronized to the system clock. An internal analog filter removes glitches on the signals, such as those caused by long PCB traces. If the signal source is far from the chip, and especially if the signals are carried on cables, the signals should be filtered or differentially transmitted.
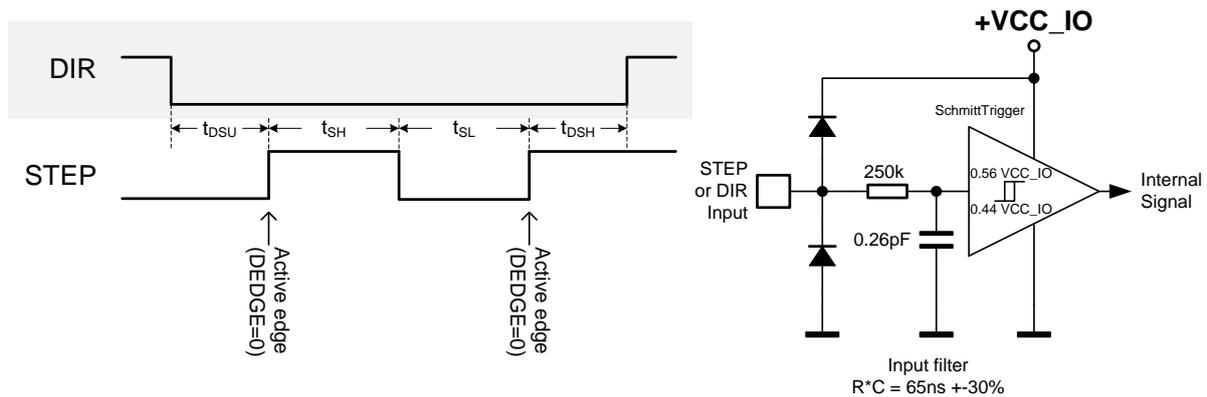
Figure 11.1 STEP and DIR timing, Input pin filter

STEP and DIR interface timing	AC-Characteristics clock period is t_{CLK}					
Parameter	**Symbol**	**Conditions**	**Min**	**Typ**	**Max**	**Unit**
step frequency (at maximum microstep resolution)	f_{STEP}				½ f_{CLK}	
fullstep frequency	f_{FS}				f_{CLK}/512	
STEP input low time *)	t_{SL}		max(t_{FILTSD}, t_{CLK}+20)			ns
STEP input high time *)	t_{SH}		max(t_{FILTSD}, t_{CLK}+20)			ns
DIR to STEP setup time	t_{DSU}		20			ns
DIR after STEP hold time	t_{DSH}		20			ns
STEP and DIR spike filtering time *)	t_{FILTSD}	rising and falling edge	36	60	85	ns
STEP and DIR sampling relative to rising CLK input	$t_{SDCLKHI}$	before rising edge of CLK input		t_{FILTSD}		ns

*) These values are valid with full input logic level swing, only. Asymmetric logic levels will increase filtering delay t_{FILTSD}, due to an internal input RC filter.

11.2 Changing Resolution

The TMC2100 includes an internal microstep table with 1024 sine wave entries to control the motor coil currents. The 1024 entries correspond to one electrical revolution or four fullsteps. The microstep resolution setting determines the step width taken within the table. Depending on the DIR input, the microstep counter is increased (DIR=0) or decreased (DIR=1) with each STEP pulse by the step width. The microstep resolution determines the increment respectively the decrement. At maximum resolution, the sequencer advances one step for each step pulse. At half resolution, it advances two steps. Increment is up to 256 steps for fullstepping. The sequencer has special provision to allow seamless switching between different microstep rates at any time. When switching to a lower microstep resolution, it calculates the nearest step within the target resolution and reads the current vector at that position. This behavior especially is important for low resolutions like fullstep and halfstep, because any failure in the step sequence would lead to asymmetrical run when comparing a motor running clockwise and counterclockwise.

EXAMPLES:	
Fullstep:	Cycles through table positions: 128, 384, 640 and 896 (45°, 135°, 225° and 315° electrical position, both coils on at identical current). The coil current in each position corresponds to the RMS-Value (0.71 * amplitude). Step size is 256 (90° electrical)
Half step:	The first table position is 64 (22.5° electrical), Step size is 128 (45° steps)
Quarter step:	The first table position is 32 (90°/8=11.25° electrical), Step size is 64 (22.5° steps)

This way equidistant steps result and they are identical in both rotation directions. Some older drivers also use zero current (table entry 0, 0°) as well as full current (90°) within the step tables. This kind of stepping is avoided because it provides less torque and has a worse power dissipation in driver and motor.

Step position	table position	current coil A	current coil B
Half step 0	64	38.3%	92.4%
Full step 0	128	70.7%	70.7%
Half step 1	192	92.4%	38.3%
Half step 2	320	92.4%	-38.3%
Full step 1	384	70.7%	-70.7%
Half step 3	448	38.3%	-92.4%
Half step 4	576	-38.3%	-92.4%
Full step 2	640	-70.7%	-70.7%
Half step 5	704	-92.4%	-38.3%
Half step 6	832	-92.4%	38.3%
Full step 3	896	-70.7%	70.7%
Half step 7	960	-38.3%	92.4%

| SETTING THE MICROSTEP RESOLUTION FOR STEP INPUT BY CFG1 AND CFG2				
CFG2	**CFG1**	**Microsteps**	**Interpolation**	**Chopper Mode**
GND	GND	1 (Fullstep)	N	SpreadCycle
GND	VCC_IO	2 (Halfstep)	N	
GND	open	2 (Halfstep)	Y, to 256 µsteps	
VCC_IO	GND	4 (Quarterstep)	N	
VCC_IO	VCC_IO	16 µsteps	N	
VCC_IO	open	4 (Quarterstep)	Y, to 256 µsteps	
open	GND	16 µsteps	Y, to 256 µsteps	
open	VCC_IO	4 (Quarterstep)	Y, to 256 µsteps	StealthChop
open	open	16 µsteps	Y, to 256 µsteps	

11.3 MicroPlyer Step Interpolator and Stand Still Detection

For each active edge on STEP, MicroPlyer produces microsteps at 256x resolution, as shown in Figure 11.2. It interpolates the time in between of two step impulses at the step input based on the last step interval. This way, up to 256 microsteps (full step input to 256 microsteps) are driven for a single step pulse.

The step rate for the interpolated 256 microsteps is determined by measuring the time interval of the previous step period and dividing it into up to 256 equal parts. The maximum time between two microsteps corresponds to 2^{20} (roughly one million system clock cycles), for an even distribution of 256 microsteps. At 16 MHz system clock frequency, this results in a minimum step input frequency of 16 Hz for MicroPlyer operation. A lower step rate causes a standstill event to be detected. At that frequency, microsteps occur at a rate of (system clock frequency)/2^{16} – 256 Hz. When a stand still is detected, the driver automatically begins standby current reduction if selected by CFG6_ENN.

> *Attention*
> MicroPlyer only works perfectly with a stable STEP frequency.
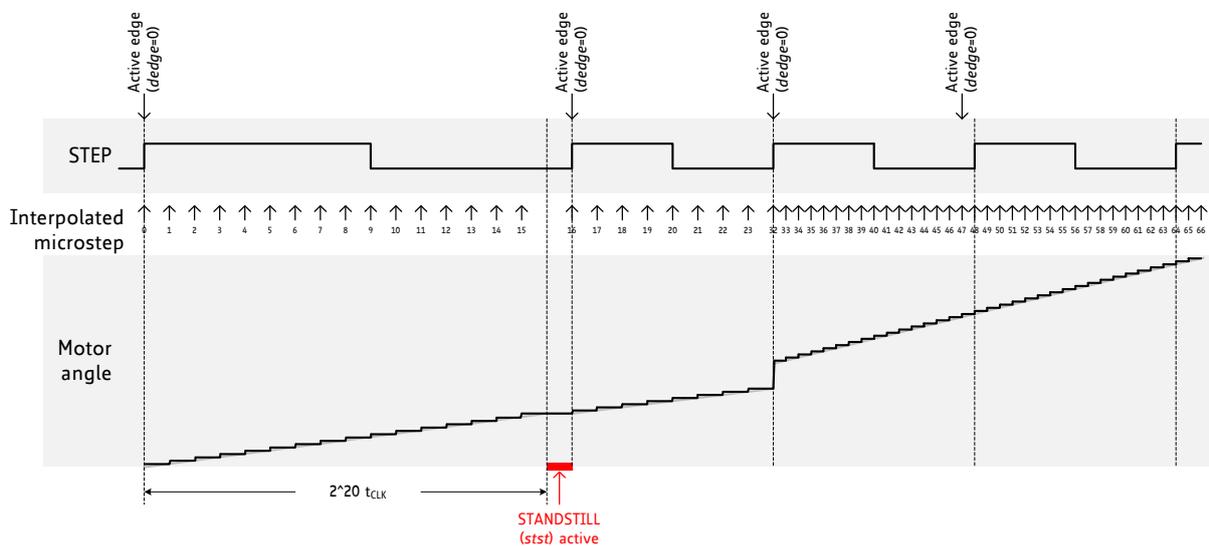
Figure 11.2 MicroPlyer microstep interpolation with rising STEP frequency (Example: 16 to 256)

In Figure 11.2, the first STEP cycle is long enough to set the *stst* bit standstill. Detection of standstill will enable the standby current reduction. This bit is cleared on the next STEP active edge. Then, the external STEP frequency increases. After one cycle at the higher rate MicroPlyer adapts the interpolated microstep rate to the higher frequency. During the last cycle at the slower rate, MicroPlyer did not generate all 16 microsteps, so there is a small jump in motor angle between the first and second cycles at the higher rate.

11.4 INDEX Output

An active INDEX output signals that the sine curve of motor coil A is at its positive zero transition. This correlates to the zero point of the microstep sequence. Usually, the cosine curve of coil B is at its maximum at the same time. Thus the index signal is active once within each electrical period, and corresponds to a defined position of the motor within a sequence of four fullsteps. The INDEX output this way allows the detection of a certain microstep pattern, and thus helps to detect a position with more precision than a stop switch can do.
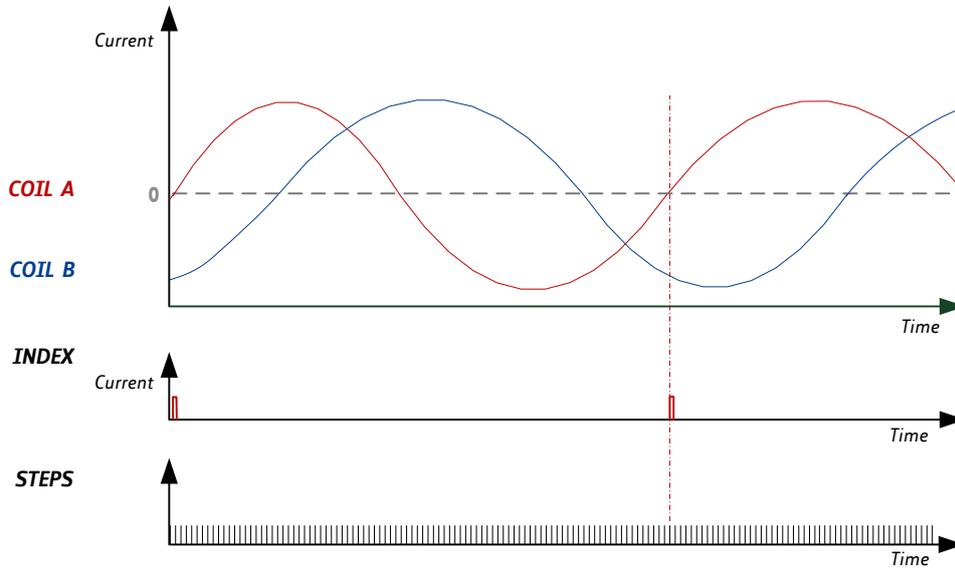

Figure 11.3 Index signal at positive zero transition of the coil A sine curve

Attention
The duration of the index pulse corresponds to the duration of the microstep. When working without interpolation at less than 256 microsteps, the index time goes down to two CLK clock cycles.

12 External Reset

The chip is loaded with default values during power on via its internal power-on reset. In order to reset the chip to power on defaults, any of the supply voltages monitored by internal reset circuitry (VSA, +5VOUT or VCC_IO) must be cycled. VCC is not monitored. Therefore VCC must not be switched off during operation of the chip. As +5VOUT is the output of the internal voltage regulator, it cannot be cycled via an external source except by cycling VSA. It is easiest and safest to cycle VCC_IO in order to completely reset the chip. Also, current consumed from VCC_IO is low and therefore it has simple driving requirements. Due to the input protection diodes not allowing the digital inputs to rise above VCC_IO level, all inputs must be driven low during this reset operation. When this is not possible, an input protection resistor may be used to limit current flowing into the related inputs.

In case, VCC becomes supplied by an external source, make sure that VCC is at a stable value above the lower operation limit once the reset ends. This normally is satisfied when generating a 3.3V VCC_IO from the +5V supply supplying the VCC pin, because it will then come up with a certain delay.

13 Clock Oscillator and Input

The clock is the timing reference for all functions: the chopper, the step execution, the current control, etc. Many parameters are scaled with the clock frequency, thus a precise reference allows a more deterministic result. The on-chip clock oscillator provides timing in case no external clock is easily available.

USING THE INTERNAL CLOCK

Directly tie the CLK input to GND near to the IC if the internal clock oscillator is to be used.

In case precise motor chopper operation is desired, it is supposed to work with an external clock source.

USING AN EXTERNAL CLOCK

When an external clock is available, a frequency of 10 MHz to 16 MHz is recommended for optimum performance. The duty cycle of the clock signal is uncritical, as long as minimum high or low input time for the pin is satisfied (refer to electrical characteristics). Up to 18 MHz can be used, when the clock duty cycle is 50%. Make sure, that the clock source supplies clean CMOS output logic levels and steep slopes when using a high clock frequency. The external clock input is enabled with the first positive polarity seen on the CLK input.

Attention

Switching off the external clock frequency prevents the driver from operating normally. Therefore be careful to switch off the motor drivers before switching off the clock (e.g. using the enable input), because otherwise the chopper would stop and the motor current level could rise uncontrolled. The short to GND detection stays active even without clock, if enabled.

13.1 Considerations on the Frequency

A higher frequency may cause more electromagnetic emission of the system and more power dissipation in the TMC2100 digital core and voltage regulator. Generally a frequency of 10 MHz to 16 MHz should be sufficient for most applications. For reduced requirements concerning the motor dynamics, a clock frequency of down to 8 MHz (or even lower) can be considered.

14 Absolute Maximum Ratings

The maximum ratings may not be exceeded under any circumstances. Operating the circuit at or near more than one maximum rating at a time for extended periods shall be avoided by application design.

Parameter	Symbol	Min	Max	Unit
Supply voltage operating with inductive load ($V_{VS} \geq V_{VSA}$)	V_{VS}, V_{VSA}	-0.5	49	V
Supply and bridge voltage max. *)	V_{VMAX}		50	V
VSA when different from to VS	V_{VSA}	-0.5	V_{VS}+0.5	V
I/O supply voltage	V_{VIO}	-0.5	5.5	V
digital VCC supply voltage (if not supplied by internal regulator)	V_{VCC}	-0.5	5.5	V
Logic input voltage	V_I	-0.5	V_{VIO}+0.5	V
Maximum current to / from digital pins and analog low voltage I/Os	I_{IO}		+/-10	mA
5V regulator output current (internal plus external load)	I_{5VOUT}		50	mA
5V regulator continuous power dissipation (V_{VM}-5V) * I_{5VOUT}	P_{5VOUT}		1	W
Power bridge repetitive output current	I_{0x}		3.0	A
Junction temperature	T_J	-50	150	°C
Storage temperature	T_{STG}	-55	150	°C
ESD-Protection for interface pins (Human body model, HBM)	V_{ESDAP}		4	kV
ESD-Protection for handling (Human body model, HBM)	V_{ESD}		1	kV

*) Stray inductivity of GND and VS connections will lead to ringing of the supply voltage when driving an inductive load. This ringing results from the fast switching slopes of the driver outputs in combination with reverse recovery of the body diodes of the output driver MOSFETs. Even small trace inductivities as well as stray inductivity of sense resistors can easily generate a few volts of ringing leading to temporary voltage overshoot. This should be considered when working near the maximum voltage.

15 Electrical Characteristics

15.1 Operational Range

Parameter	Symbol	Min	Max	Unit
Junction temperature	T_J	-40	125	°C
Supply voltage (using internal +5V regulator)	V_{VS}, V_{VSA}	5.5	46	V
Supply voltage (internal +5V regulator bridged: V_{VCC}=V_{VSA}=V_{VS})	V_{VS}	4.7	5.4	V
I/O supply voltage	V_{VIO}	3.00	5.25	V
VCC voltage when using optional external source (supplies digital logic and charge pump)	V_{VCC}	4.6	5.25	V
RMS motor coil current per coil (value for design guideline) for QFN36 5x6 package resp. TQFP-48 package	$I_{RMS-QFN36}$ $I_{RMS-TQFP48}$		1.2 1.4	A
Peak output current per motor coil output (sine wave peak) using external or internal current sensing	I_{0x}		2.0	A
Peak output current per motor coil output (sine wave peak) for short term operation. Limit $T_J \leq$ 105°C, e.g. for 100ms short time acceleration phase below 50% duty cycle.	I_{0x}		2.5	A

15.2 DC and Timing Characteristics

DC characteristics contain the spread of values guaranteed within the specified supply voltage range unless otherwise specified. Typical values represent the average value of all parts measured at +25 °C. Temperature variation also causes stray to some values. A device with typical values will not leave Min/Max range within the full temperature range.

Power supply current	DC-Characteristics $V_{VS} = V_{VSA} = 24.0V$						
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Total supply current, driver disabled $I_{VS} + I_{VSA} + I_{VCC}$	I_S	f_{CLK}=16 MHz		15	22	mA
Total supply current, operating, $I_{VS} + I_{VSA} + I_{VCC}$	I_S	f_{CLK}=16 MHz, 23.4 kHz chopper, no load		19		mA
Idle supply current from VS, charge pump operating	I_{VS0}	f_{CLK}=0 Hz, driver disabled		0.25	0.5	mA
Static supply current from VSA with VCC supplied by 5VOUT	I_{VSA0}	f_{CLK}=0Hz, includes VCC supply current	1.4	2	3	mA
Supply current, driver disabled, dependency on CLK frequency	I_{VCCx}	f_{CLK} variable, additional to I_{VSA0}		0.8		mA/MHz
Internal current consumption from 5V supply on VCC pin	I_{VCC}	f_{CLK}=16 MHz, 23.4 kHz chopper		16		mA
IO supply current (typ. at 5 V)	I_{VIO}	no load on outputs, inputs at V_{IO} or GND Excludes pullup / pull-down resistors		15	30	µA

Motor driver section	DC- and Timing-Characteristics $V_{VS} = 24.0V$						
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
RDS$_{ON}$ lowside MOSFET	R_{ONL}	measure at 100 mA, 25 °C, static state		0.4	0.5	Ω
RDS$_{ON}$ highside MOSFET	R_{ONH}	measure at 100 mA, 25 °C, static state		0.5	0.6	Ω
slope, MOSFET turning on	t_{SLPON}	measured at 700 mA load current (resistive load)	50	120	220	ns
slope, MOSFET turning off	t_{SLPOFF}	measured at 700 mA load current (resistive load)	50	120	220	ns
Current sourcing, driver off	I_{OIDLE}	O_{xx} pulled to GND	120	180	250	µA

Charge pump	DC-Characteristics						
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Charge pump output voltage	$V_{VCP}-V_{VS}$	operating, typical f_{chop}<40 kHz	4.0	V_{VCC} - 0.3	V_{VCC}	V
Charge pump voltage threshold for undervoltage detection	$V_{VCP}-V_{VS}$	using internal 5V regulator voltage	3.3	3.6	3.8	V
Charge pump frequency	f_{CP}			1/16 f_{CLKOSC}		

Linear regulator	DC-Characteristics $V_{VS} = V_{VSA} = 24.0\,V$					
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output voltage	V_{5VOUT}	$I_{5VOUT} = 0\,mA$ $T_J = 25\,°C$	4.80	5.0	5.25	V
Output resistance	R_{5VOUT}	Static load		3		Ω
Deviation of output voltage over the full temperature range	$V_{5VOUT(DEV)}$	$I_{5VOUT} = 16\,mA$ $T_J = $ full range		+/-30	+/-100	mV
Deviation of output voltage over the full supply voltage range	$V_{5VOUT(DEV)}$	$I_{5VOUT} = 0\,mA$ $V_{VSA} = $ variable		+/-15	+/-30	mV / 10V
Deviation of output voltage over the full supply voltage range	$V_{5VOUT(DEV)}$	$I_{5VOUT} = 16\,mA$ $V_{VSA} = $ variable		-38	+/-75	mV / 10V

Clock oscillator and input	Timing-Characteristics					
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Clock oscillator frequency	f_{CLKOSC}	$t_J=-50\,°C$	9	12.4		MHz
Clock oscillator frequency	f_{CLKOSC}	$t_J=50\,°C$	10.1	13.2	17.2	MHz
Clock oscillator frequency	f_{CLKOSC}	$t_J=150\,°C$		13.4	18	MHz
External clock frequency (operating)	f_{CLK}		4	10-16	18	MHz
External clock high / low level time	t_{CLKH} / t_{CLKL}	CLK driven to $0.1\ V_{VIO}$ / $0.9\ V_{VIO}$	10			ns
External clock first cycle triggering switching to external clock source	t_{CLKH1}	CLK driven high	30	25		ns

Detector levels	DC-Characteristics					
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
V_{VSA} undervoltage threshold for RESET	V_{UV_VSA}	V_{VSA} rising	3.8	4.2	4.6	V
V_{5VOUT} undervoltage threshold for RESET	V_{UV_5VOUT}	V_{5VOUT} rising		3.5		V
V_{VCC_IO} undervoltage threshold for RESET	V_{UV_VIO}	V_{VCC_IO} rising (delay typ. 10 µs)	2.1	2.55	3.0	V
V_{VCC_IO} undervoltage detector hysteresis	$V_{UV\_VIOHYST}$			0.3		V
Short to GND detector threshold ($V_{VS} - V_{0x}$)	V_{OS2G}		2	2.5	3	V
Short to GND detector delay (high side switch on to short detected)	t_{S2G}	High side output clamped to V_{VS}-3V	0.8	1.3	2	µs
Overtemperature recovery	t_{OTPW}	Temperature falling	100	120	140	°C
Overtemperature shutdown	t_{OT}	Temperature rising	135	150	170	°C

Sense resistor voltage levels	DC-Characteristics f_{CLK}=16MHz					
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Sense input peak threshold voltage	V_{SRT}	Sine wave peak, low hysteresis		320		mV
Sense input tolerance / motor current full scale tolerance -using internal reference	I_{COIL}		-5		+5	%
Sense input tolerance / motor current full scale tolerance -using external reference voltage	I_{COIL}	Analog scaling via AIN	-2		+2	%
Internal resistance from pin BRxy to internal sense comparator (additional to sense resistor)	R_{BRxy}			20		mΩ

Digital pins	DC-Characteristics					
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input voltage low level	V_{INLO}		-0.3		0.3 V_{VIO}	V
Input voltage high level	V_{INHI}		0.7 V_{VIO}		V_{VIO}+0.3	V
Input Schmitt trigger hysteresis	V_{INHYST}			0.12 V_{VIO}		V
Output voltage low level	V_{OUTLO}	I_{OUTLO} = 2 mA			0.2	V
Output voltage high level	V_{OUTHI}	I_{OUTHI} = -2 mA	V_{VIO}-0.2			V
Input leakage current	I_{ILEAK}		-10		10	µA
Pullup / pull-down resistors used for tristate detection on CFGx	R_{PU}/R_{PD}		132	166	200	kΩ
Tristate detection toggle frequency	f_{TOGGLE}			1/1024		f_{CLK}
Time to detect open CFG pin	t_{CFG}				3072	t_{CLK}
Digital pin capacitance	C			3.5		pF

AIN/IREF input	DC-Characteristics					
Parameter	Symbol	Conditions	Min	Typ	Max	Unit
AIN_IREF input resistance to 2.5V (=5VOUT/2)	R_{AIN}	Measured to GND	260	330	400	kΩ
AIN_IREF input voltage range for linear current scaling	V_{AIN}	Measured to GND	0	0.5-2.4	V_{5VOUT}/2	V
AIN_IREF open input voltage level	V_{AINO}	Open circuit voltage		V_{5VOUT}/2		V
AIN_IREF input resistance to GND for reference current input	R_{IREF}	Measured to GND	0.8	1	1.2	kΩ
AIN_IREF current amplification for reference current to coil current at maximum setting	$I_{REFAMPL}$	I_{IREF} = 0.25 mA		3000		Times
Motor current full scale tolerance -using RDSon measurement	I_{COIL}	I_{IREF} = 0.25 mA	-10		+10	%

15.3 Thermal Characteristics

The following table shall give an idea on the thermal resistance of the package. The thermal resistance for a four layer board will provide a good idea on a typical application. Actual thermal characteristics will depend on the PCB layout, PCB type and PCB size. The thermal resistance will benefit from thicker CU (inner) layers for spreading heat horizontally within the PCB. Also, air flow will reduce thermal resistance.

A thermal resistance of 24 K/W for a typical board means, that the package is capable of continuously dissipating 4.1 W at an ambient temperature of 25°C with the die temperature staying below 125°C.

Parameter	Symbol	Conditions	Typ	Unit
Typical power dissipation	P_D	StealthChop or SpreadCycle, 0.92 A RMS in two phase motor, sinewave, 40 or 20 kHz chopper, 24V, internal supply, 84°C peak surface of package (motor QSH4218-035-10-027)	2.6	W
Thermal resistance junction to ambient on a multilayer board	R_{TMJA}	Dual signal and two internal power plane board (2s2p) as defined in JEDEC EIA JESD51-5 and JESD51-7 (FR4, 35 µm CU, 84 mm x 55 mm, d=1.5 mm)	24	K/W
Thermal resistance junction to ambient on a multilayer board for TQFP-EP48 package	R_{TMJA}	Dual signal and two internal power plane board (2s2p) as defined in JEDEC EIA JESD51-5 and JESD51-7 (FR4, 35µm CU, 70mm x 133mm, d=1.5mm)	21	K/W
Thermal resistance junction to board	R_{TJB}	PCB temperature measured within 1mm distance to the package	8	K/W
Thermal resistance junction to case	R_{TJC}	Junction temperature to heat slug of package	3	K/W

Table 15.1 Thermal Characteristics QFN5x6 and TQFP-EP48

The thermal resistance in an actual layout can be tested by checking for the heat up caused by the standby power consumption of the chip. When no motor is attached, all power seen on the power supply is dissipated within the chip.

> *Note*
> A spread-sheet for calculating TMC2100 power dissipation is available on www.trinamic.com.

16 Layout Considerations

16.1 Exposed Die Pad

The TMC2100 uses its die attach pad to dissipate heat from the drivers and the linear regulator to the board. For best electrical and thermal performance, use a reasonable amount of solid, thermally conducting vias between the die attach pad and the ground plane. The printed circuit board should have a solid ground plane spreading heat into the board and providing for a stable GND reference.

16.2 Wiring GND

All signals of the TMC2100 are referenced to their respective GND. Directly connect all GND pins under the device to a common ground area (GND, GNDP, GNDA and die attach pad). The GND plane right below the die attach pad should be treated as a virtual star point. For thermal reasons, the PCB top layer shall be connected to a large PCB GND plane spreading heat within the PCB.

> *Attention*
> Especially the sense resistors are susceptible to GND differences and GND ripple voltage, as the microstep current steps make up for voltages down to 0.5 mV. No current other than the sense resistor current should flow on their connections to GND and to the TMC2100. Optimally place them close to the IC, with one or more vias to the GND plane for each sense resistor. The two sense resistors for one coil should not share a common ground connection trace or vias, as also PCB traces have a certain resistance.

16.3 Supply Filtering

The 5VOUT output voltage ceramic filtering capacitor (4.7 µF recommended) should be placed as close as possible to the 5VOUT pin, with its GND return going directly to the GNDA pin. This ground connection shall not be shared with other loads or additional vias to the GND plan. Use as short and as thick connections as possible. For best microstepping performance and lowest chopper noise an additional filtering capacitor should be used for the VCC pin to GND, to avoid charge pump and digital part ripple influencing motor current regulation. Therefore place a ceramic filtering capacitor (470 nF recommended) as close as possible (1-2mm distance) to the VCC pin with GND return going to the ground plane. VCC can be coupled to 5VOUT using a 2.2 Ω or 3.3 Ω resistor in order to supply the digital logic from 5VOUT while keeping ripple away from this pin.

A 100 nF filtering capacitor should be placed as close as possible to the VSA pin to ground plane. The motor supply pins VS should be decoupled with an electrolytic capacitor (low ESR type 47 µF or larger is recommended) and a ceramic capacitor, placed close to the device.

Take into account that the switching motor coil outputs have a high dV/dt. Thus capacitive stray into high resistive signals can occur, if the motor traces are near other traces over longer distances.

16.4 Layout Example: TMC2100-BOB

The tiny TMC2100-BOB is a breakout board for the TMC2100 integrated standalone stepper driver. It allows access to all configuration hardware pins.

Schematic (can use TMC2100 or TMC2130 optional, Pinning shown for both)
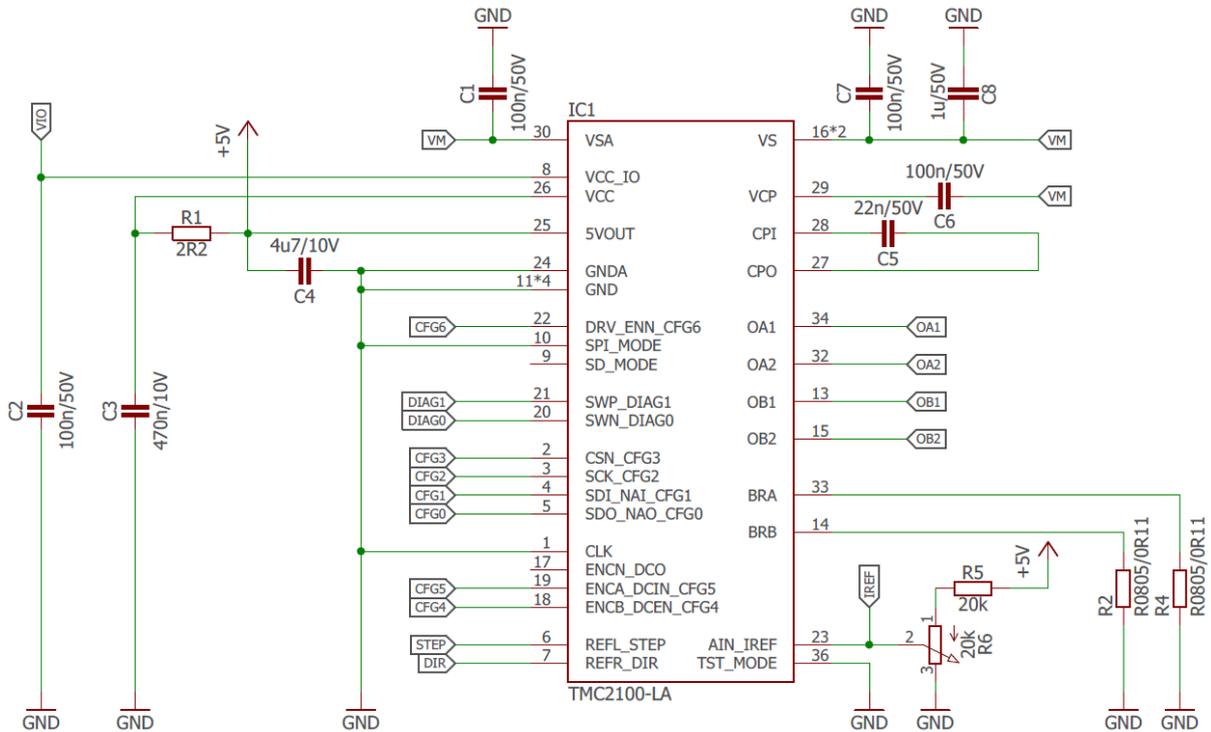
1 - Top Layer (assembly side)

2 - Inner Layer 1
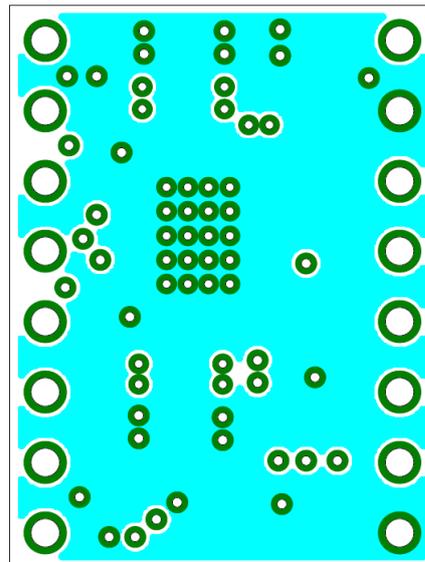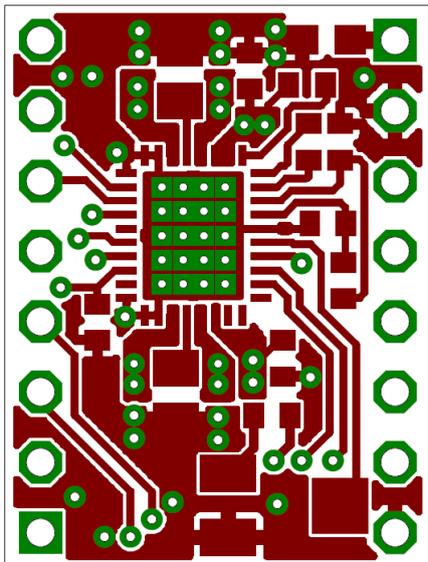
3 - Inner Layer 2
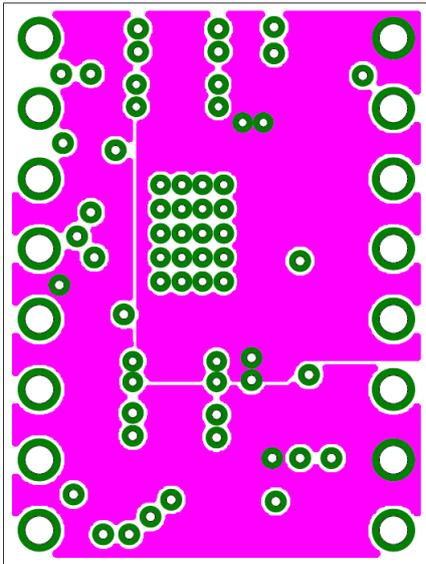
4 - Bottom Layer
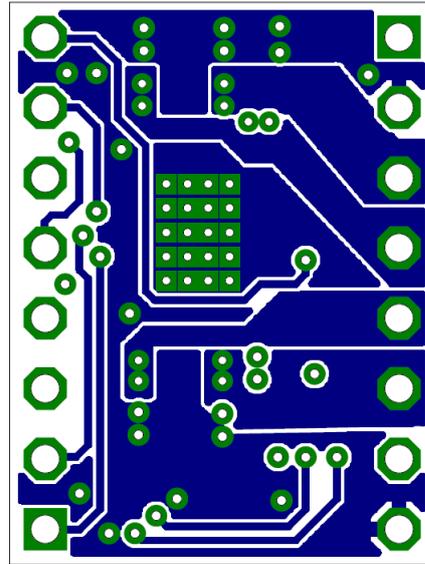
Components
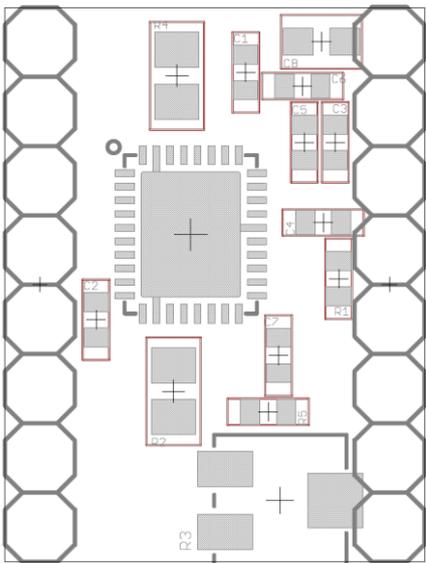
Figure 16.1 TMC2100-BOB as layout example

17 Package Mechanical Data

All length units are given in millimeters.

17.1 Dimensional Drawings QFN36 5x6

Attention: Drawings not to scale.
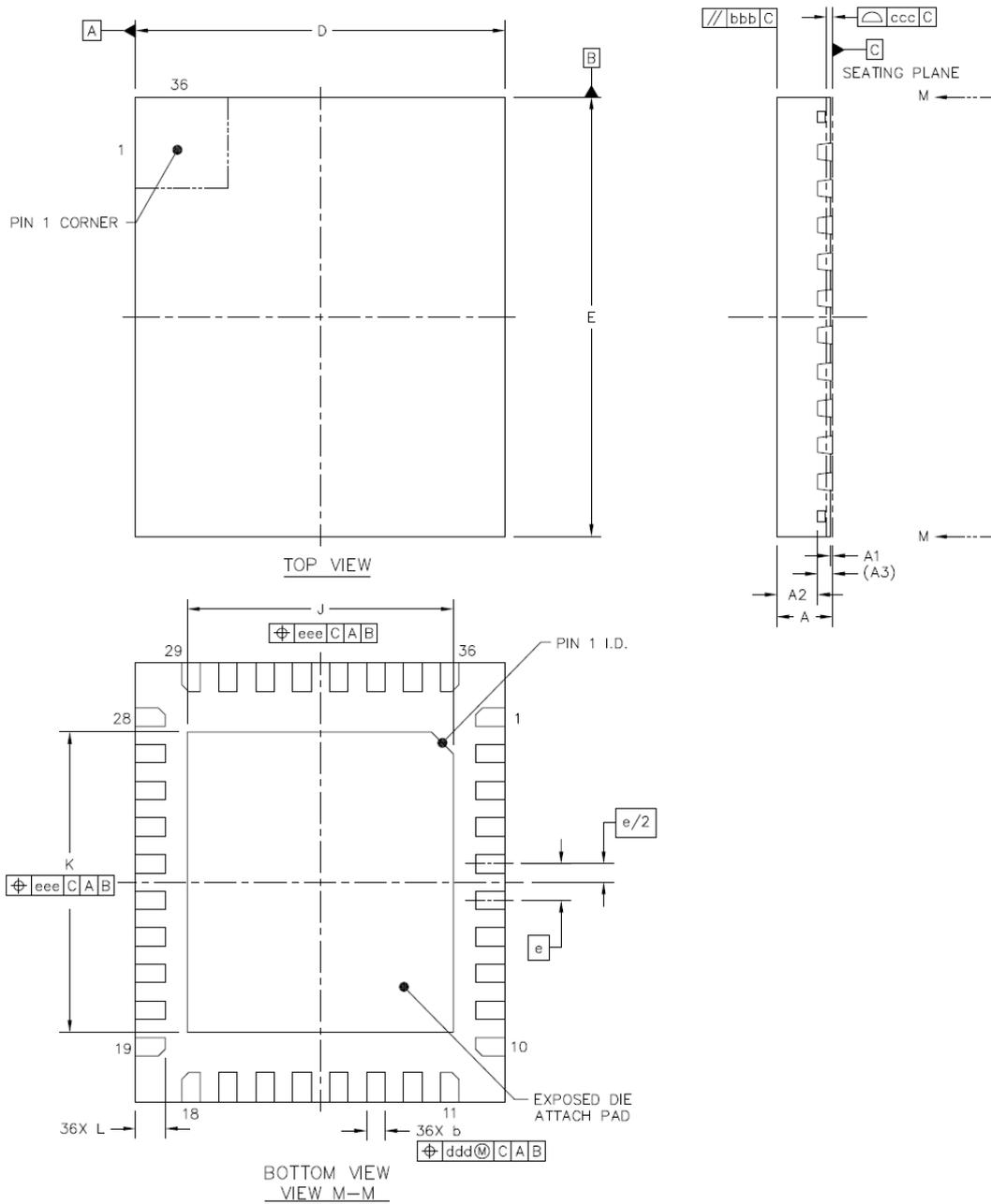
Figure 17.1 Dimensional drawings QFN 5x6

Parameter	Ref	Min	Nom	Max
total thickness	A	0.8	0.85	0.9
stand off	A1	0	0.035	0.05
mold thickness	A2	-	0.65	-
lead frame thickness	A3		0.203	
lead width	b	0.2	0.25	0.3
body size X	D	4.9	5	5.1
body size Y	E	5.9	6	6.1
lead pitch	e		0.5	
exposed die pad size X	J	3.5	3.6	3.7
exposed die pad size Y	K	4.0	4.1	4.2
lead length	L	0.35	0.4	0.45
mold flatness	bbb			0.1
coplanarity	ccc			0.08
lead offset	ddd			0.1
exposed pad offset	eee			0.1

17.2 Dimensional Drawings TQFP-EP48

Attention: Drawings not to scale.
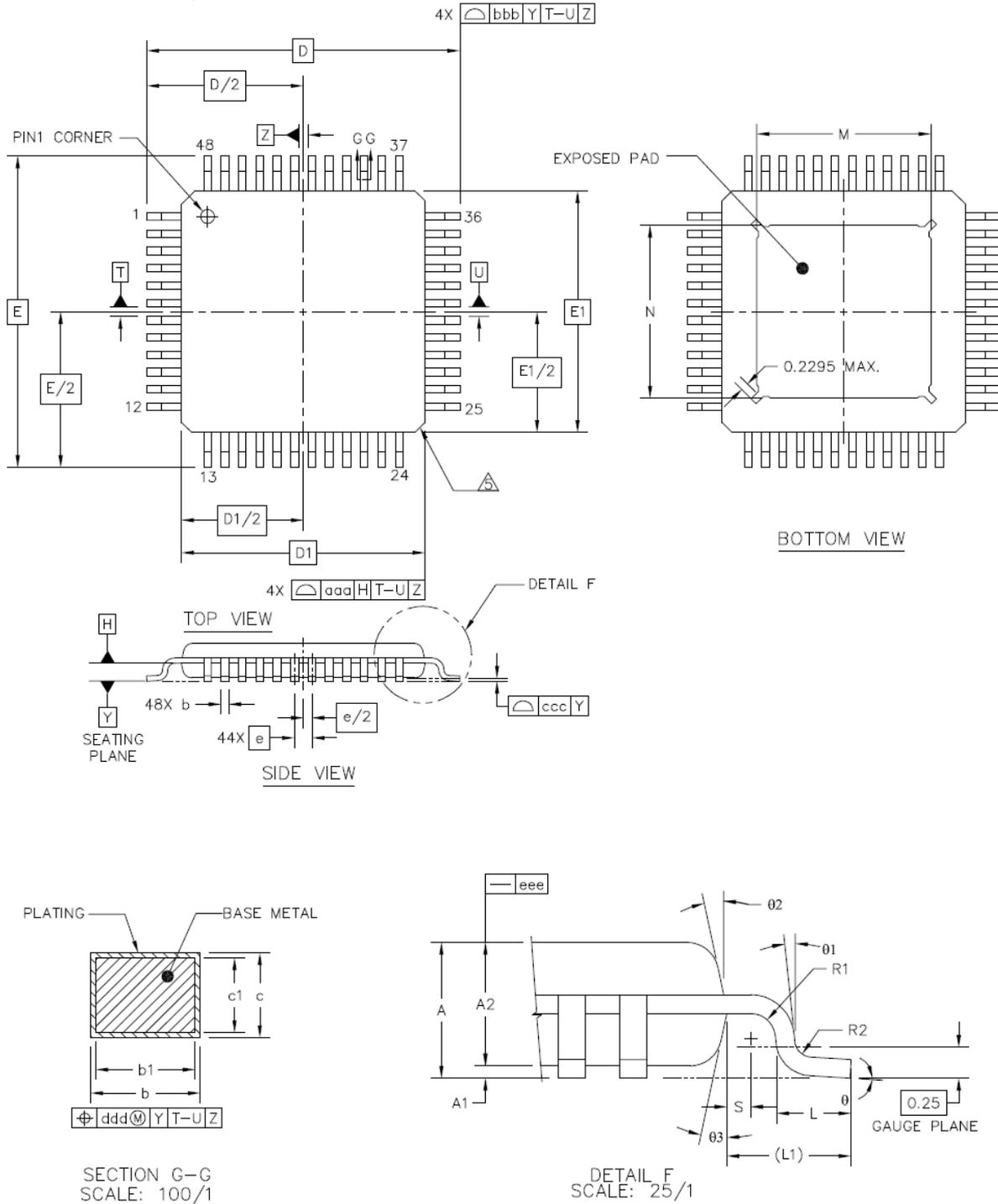
Figure 17.2 Dimensional drawings TQFP-EP48

Parameter	Ref	Min	Nom	Max
total thickness	A	-	-	1.2
stand off	A1	0.05	-	0.15
mold thickness	A2	0.95	1	1.05
lead width (plating)	b	0.17	0.22	0.27
lead width	b1	0.17	0.2	0.23
lead frame thickness (plating)	c	0.09	-	0.2
lead frame thickness	c1	0.09	-	0.16
body size X (over pins)	D		9.0	
body size Y (over pins)	E		9.0	
body size X	D1		7.0	
body size Y	E1		7.0	
lead pitch	e		0.5	
lead	L	0.45	0.6	0.75
footprint	L1		1 REF	
	Θ	0°	3.5°	7°
	Θ1	0°	-	-
	Θ2	11°	12°	13°
	Θ3	11°	12°	13°
	R1	0.08	-	-
	R2	0.08	-	0.2
	S	0.2	-	-
exposed die pad size X	M	4.9	5	5.1
exposed die pad size Y	N	4.9	5	5.1
package edge tolerance	aaa			0.2
lead edge tolerance	bbb			0.2
coplanarity	ccc			0.08
lead offset	ddd			0.08
mold flatness	eee			0.05

17.3 Package Codes

Type	Package	Temperature range	Code & marking
TMC2100-LA	QFN36 (RoHS)	-40°C ... +125°C	TMC2100-LA
TMC2100-TA	TQFP-EP48 (RoHS)	-40°C ... +125°C	TMC2100-TA
TMC2100-LA-T TMC2100-TA-T	Tape on reel packaged devices		

18 Disclaimer

TRINAMIC Motion Control GmbH & Co. KG does not authorize or warrant any of its products for use in life support systems, without the specific written consent of TRINAMIC Motion Control GmbH & Co. KG. Life support systems are equipment intended to support or sustain life, and whose failure to perform, when properly used in accordance with instructions provided, can be reasonably expected to result in personal injury or death.

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19 ESD Sensitive Device

The TMC2100 is an ESD sensitive CMOS device sensitive to electrostatic discharge. Take special care to use adequate grounding of personnel and machines in manual handling. After soldering the devices to the board, ESD requirements are more relaxed. Failure to do so can result in defect or decreased reliability.

20 Designed for Sustainability

Sustainable growth is one of the most important and urgent challenges today. We at Trinamic try to contribute by designing highly efficient IC products, to minimize energy consumption, ensure best customer experience and long-term satisfaction by smooth and silent run, while minimizing the demand for external resources, e.g. for power supply, cooling infrastructure, reduced motor size and magnet material by intelligent control interfaces and advanced algorithms.

Please help and design efficient and durable products made for a sustainable world.

21 Table of Figures

22 Revision History

Version	Date	Author BD= Bernhard Dwersteg SD= Sonja Dwersteg	Description
V0.90	2014-OKT-30	SD	First complete version
V1.00	2014-NOV-26	BD	Corrected package dimensions and motor current table
V1.05	2016-JUL-25	BD	Corrected half step table in chapter 11.2, rewording for clarity
V1.06	2016-NOV-18	BD	Added –TA package, Changed order / rewording of chapter 7-9.
V1.07	2017-MAY-15	BD	Corrected example 1 – drive CFG1 to GND / open
V1.08	2018-MAY-16	BD	Added hint for CFG pin open detection, minor fixes
V1.09	2018-OCT-10	BD	Added description for ERROR output, minor fixes
V1.10	2019-NOV-07	BD	Minor fixes, new pict., sustainability chapter
V1.11	2020-JUN-03	BD	Updated logo, minor fixes

Table 22.1 Document Revisions

23 References

[TMC2100-EVAL]   TMC2100-EVAL Manual

[AN001] Trinamic Application Note 001 - Parameterization of SpreadCycle™, www.trinamic.com

Calculation sheet TMC5130_TMC2130_TMC2100_Calculations.xlsx