

TMC2210

36V 2A_{RMS}+ Standalone Integrated S/D Stepper Driver

General Description

The TMC2210 is a high-performance stepper motor driver IC with configuration options through package pins and additional diagnostic outputs.

It combines industries' most advanced stepper motor driver based on the 256 microsteps built-in indexer and two fully integrated 36V, 3.0A_{MAX} H-Bridges plus non-dissipative integrated current sensing (ICS).

ADI-Trinamic's StealthChop2 chopper ensures absolutely noiseless operation combined with maximum efficiency and best motor torque.

High integration, high energy efficiency, and a small form factor enable miniaturized and scalable systems for cost-effective solutions while giving best in class performance.

The H-Bridge FETs have very low impedance resulting in high driving efficiency and minimal heat generated. The typical total R_{ON} (high side + low side) is 0.23Ω.

The integrated Overcurrent Protection (OCP) adapts to the selected motor current range.

The maximum RMS current per H-Bridge is I_{RMS} = 2.1A_{RMS} at room temperature assuming a four-layer PCB.

Since this current is limited by thermal considerations the actual maximum RMS current would depend on the thermal characteristic of the application (PCB ground planes, heatsinks, ventilation, etc.).

The maximum full-scale current per H-Bridge is I_{FS} = 3.0A and can be set by an external resistor connected to IREF. This current is defined as the maximum current setting of the embedded current drive regulation circuit.

The non-dissipative ICS eliminates the bulky external power resistors resulting in a dramatic space and power saving compared to mainstream applications based on external sense resistor.

The TMC2210 features diagnostic outputs and protections such as short protection/OCP, thermal shutdown, under-voltage lockout (UVLO).

During thermal shutdown and UVLO events, the driver is disabled.

The TMC2210 is available in a small TQFN32 5mm x 5mm package and a thermally optimized TSSOP38 9.7mm x 4.4mm with exposed pad.

Applications

- Textile, Sewing Machines, Knitting Machines
- 3D Printers, ID Printers/Card Printers

- Office Automation, Printers, Scanners, Copy Machines
- ATM, Cash Recycler, Bill Validators, Cash Machines
- Point-of-Sale (POS) Equipment
- Pumps and Valve Control

Benefits and Features

- Voltage Range 4.5V to 36V DC
- Low R_{DS(ON)} (HS + LS): 230mΩ Typical (T_A = 25°C)
- Current Ratings per H-Bridge (Typical at 25°C):
 - I_{MAX} = 5.0A (Bridge Peak Current)
 - I_{RMS} = 2.1A_{RMS} (3A Sine Wave Peak)
- Fully Integrated Lossless Current Sensing
- Step/Direction (S/D) Interface with MicroPlyer Step Interpolation
- Highest Resolution 256 Microsteps per Full Step
- StealthChop2 Silent Motor Operation
- SpreadCycle Highly Dynamic Current Control
- Full Protection and Diagnostics
- Overvoltage Protection Output
- Compact 5mm x 5mm TQFN32 Package or 9.7mm x 4.4mm TSSOP38

Simplified Block Diagram

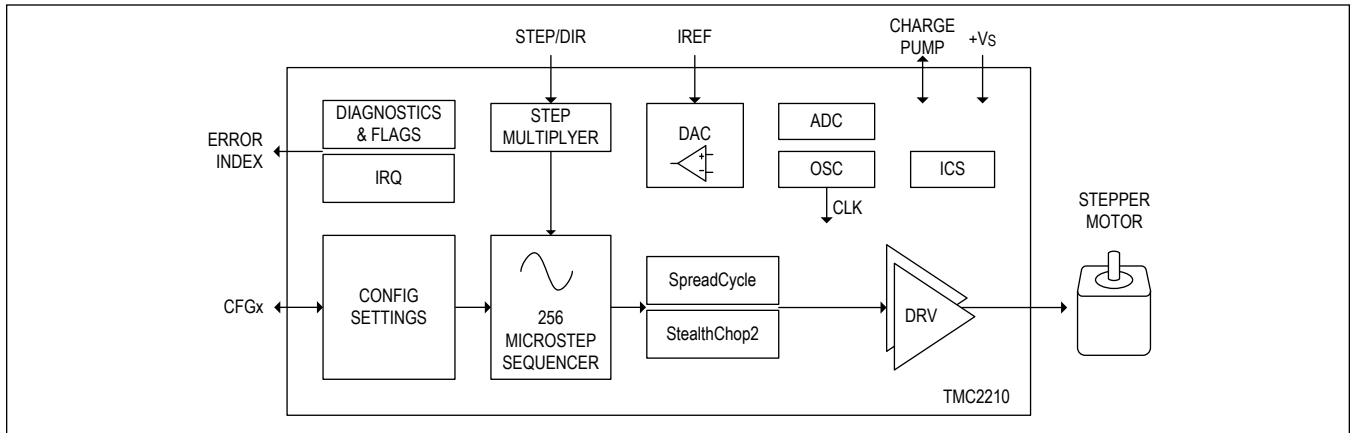


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TMC2210

36V 2A_{RMS}+ Standalone Integrated S/D Stepper
Driver

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Absolute Maximum Ratings

V _S to GND	-0.3V to 41V	IREF to GND	-0.3V to min (2.2, V _{DD1V8} + 0.3)V
V _{DD1V8} to GND	-0.3V to min (2.2, V _S + 0.3)V	V _{CC_IO} to GND	-0.3V to 5.5V
AGND to GND	-0.3V to +0.3V	Logic Input/Output Voltage to GND	-0.3V to V _{CC_IO} + 0.3V
OUT1A, OUT2A, OUT1B, OUT2B	-0.3V to V _S + 0.3V	OV to GND	-0.3V to 6V
V _{CP} to GND	V _S - 0.3V to min (44, V _S + 6)V	Operating Temperature Range	-40°C to 125°C
CPO to GND	V _S - 0.3V to min (44, V _S + 6)V	Junction Temperature	+165°C
CPI to GND	-0.3V to min (41, V _S + 0.3)V	Storage Temperature Range	-65°C to +150°C
SLEEPN to GND	-0.3V to V _S + 0.3V	Soldering Temperature (reflow)	+260°C

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Information

TQFN32 5mm x 5mm

Package Code	T3255+5C
Outline Number	21-0140
Land Pattern Number	90-0013
Thermal Resistance, Single-Layer Board:	
Junction to Ambient (θ _{JA})	47°C/W
Junction to Case (θ _{JC})	1.7°C/W
Thermal Resistance, Four-Layer Board:	
Junction to Ambient (θ _{JA})	29°C/W
Junction to Case (θ _{JC})	1.7°C/W

TSSOP38 9.7mm x 4.4mm EP

Package Code	U38E+3C
Outline Number	21-0714
Land Pattern Number	90-0435
Thermal Resistance, Four-Layer Board:	
Junction to Ambient (θ _{JA})	25°C/W
Junction to Case (θ _{JC})	1°C/W

For the latest package outline information and land patterns (footprints), go to www.maximintegrated.com/packages. Note that a "+", "#", or "L" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to www.maximintegrated.com/thermal-tutorial.

Electrical Characteristics

(V_S = 4.5V to 36V, R_{REF} = from 12kΩ to 24kΩ, Typical Values assume T_A = 25°C and V_S = 24V, Limits are 100% tested at T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER SUPPLY						
Supply Voltage Range	V _S		4.5		36	V
Sleep Mode Current Consumption	I _{VS}	V(SLEEPN) = 0		4	18	μA

Electrical Characteristics (continued)

(V_S = 4.5V to 36V, R_{REF} = from 12kΩ to 24kΩ, Typical Values assume T_A = 25°C and V_S = 24V, Limits are 100% tested at T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Quiescent Current Consumption	I _{VS}	V(SLEEPN) = 1, V(DRV_ENN) = 1		3.5	5	mA
1.8V Regulator Output Voltage	V _{VDD}	V _S = 4.5V		1.8		V
V _{DD} Current Limit	I _{V18LIM}		20			mA
Charge Pump Voltage	V _{CP}			V _S + 2.7		V
Logic I/O Supply Voltage Range	V _{CC_IO}		2.2		5.5	V
Sleep Mode Current Consumption	I _{VCC_IO}	V(SLEEPN) = 0		5	10	μA
Quiescent Current Consumption	I _{VCC_IO}	V(SLEEPN) = 1		35	60	μA
LOGIC LEVEL INPUTS-OUTPUTS						
Input Voltage Level - High	V _{IH}		0.7 x V _{CC_IO}			V
Input Voltage Level - Low	V _{IL}		0.3 x V _{CC_IO}			V
Input Hysteresis	V _{HYS}		0.15 x V _{CC_IO}			V
Internal Pullup/Pulldown Resistance	R _{PULL}	to GND or to V _{CC_IO}	60	100	140	kΩ
Input Leakage	I _{nLeak}	Inputs without pullup/pulldown resistance	-1		+1	μA
Output Logic-Low Voltage	V _{OL}	I _{LOAD} = 5mA			0.4	V
Push-Pull Output Logic-High Voltage	V _{OH}	I _{LOAD} = 5mA	V _{CC_IO} - 400mV			
Open-Drain Output Logic High Leakage Current	I _{OH}	V(PIN) = 5.5V	-1		+1	μA
SLEEPN Voltage Level High	V _{IHSLEEPN}		0.9			V
SLEEPN Voltage Level Low	V _{ILSLEEPN}				0.6	V
SLEEPN Pulldown Input Resistance	R _{PD} SLEEPN		0.8	1.5		MΩ
OUTPUT SPECIFICATIONS						
Output ON-Resistance Low Side	R _{ONLS}	CFG3/CFG2 = 10		0.11	0.2	Ω
		CFG3/CFG2 = 01		0.15	0.28	
		CFG3/CFG2 = 00		0.28	0.54	
Output ON-Resistance High Side	R _{ONHS}			0.12	0.22	Ω
Output Leakage	I _{LEAK}		-5		+5	μA
Output Slew Rate	SR			400		V/μs

Electrical Characteristics (continued)

(V_S = 4.5V to 36V, R_{REF} = from 12kΩ to 24kΩ, Typical Values assume T_A = 25°C and V_S = 24V, Limits are 100% tested at T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
PROTECTION CIRCUITS						
Overcurrent Protection Threshold	OCP	CFG3/CFG2 = 10	5.0			A
		CFG3/CFG2 = 01	3.33			
		CFG3/CFG2 = 00	1.67			
Overcurrent Protection Blanking Time	T _{OCP}		0.9	1.5	2.3	μs
UVLO Threshold on V _S	UVLO	V _S falling	3.75	3.9	4.05	V
UVLO Threshold on V _S Hysteris	UVLOHYS			0.12		V
UVLO Threshold on V _{CC_IO}	UVLO	V _{CC_IO} falling	0.9	1.5	1.95	
V _{CC_IO} UVLO Hysteresis	UVLOVCCH			100		mV
Thermal Protection Threshold Temperature	TSD			165		°C
Thermal Protection Temperature Hysteresis				20		°C
CURRENT REGULATION						
IREF Pin Resistor Range	R _{REF}		12		60	kΩ
IREF Output Voltage	V _{REF}		0.882	0.9	0.918	V
Full-Scale Current Constant	KIFS	IFS = 1A		11.75		A x kΩ
Full-Scale Current Constant	KIFS	IFS = 2A		24		A x kΩ
Full-Scale Current Constant	KIFS	IFS = 3A		36		A x kΩ
Regulation Accuracy	DITRIP1	Output current from 7% to 100% FS, R _{REF} = 12kΩ	-5		+5	%
FUNCTIONAL TIMINGS						
SLEEP Time	t _{SLEEP}	SLEEPN = 0 to OUT_ three state			50	μs
Wake-Up Time from Sleep	TWAKE	SLEEPN = 1 to normal operation			2.5	ms
Enable Time	TEN	Time from DRV_ENN pin falling edge to driver on			1.5	μs
Disable Time	TEN	Time from DRV_ENN pin rising edge to driver off			6	μs
CLOCK						
Internal Clock Frequency	f _{CLK}	min/max values take temperature coefficient into account	11.9	12.5	13.2	MHz
STEP/DIR TIMINGS						
Step Frequency	f _{STEP}				f _{CLK} /4	
Fullstep Frequency	f _{FS}				f _{CLK} /512	

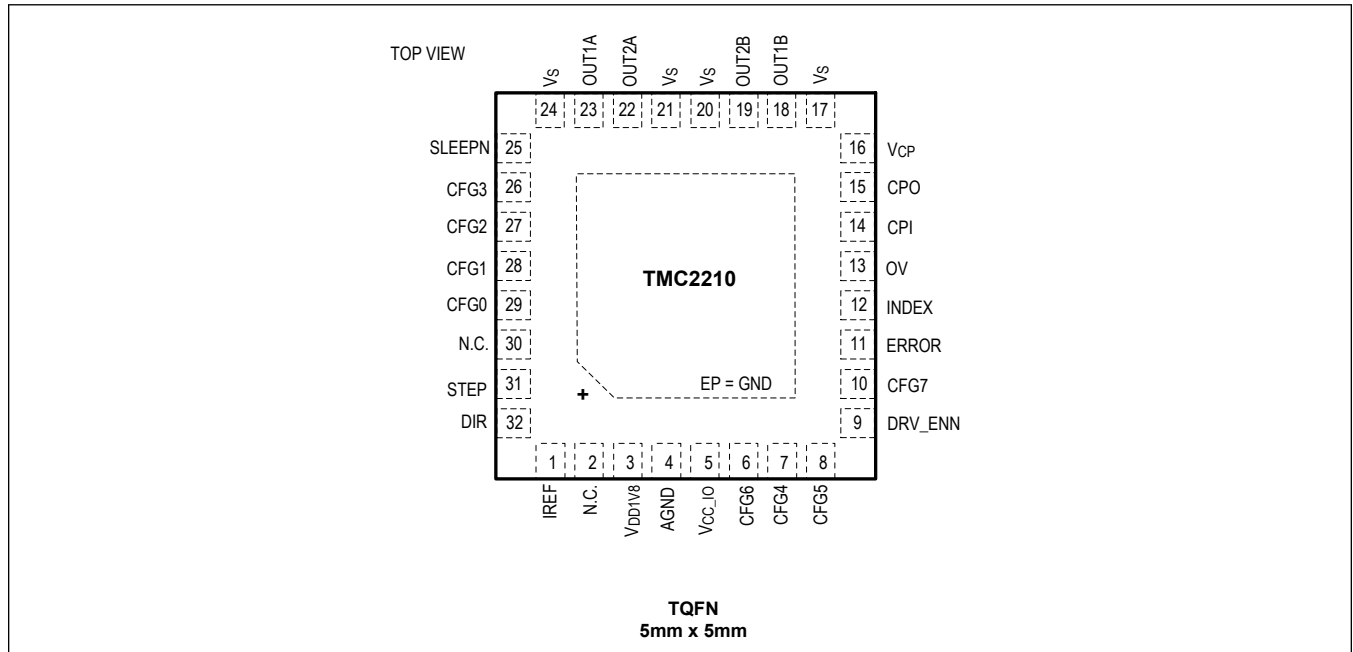
Electrical Characteristics (continued)

(V_S = 4.5V to 36V, R_{REF} = from 12kΩ to 24kΩ , Typical Values assume T_A = 25°C and V_S = 24V, Limits are 100% tested at T_A = +25°C. Limits over the operating temperature range and relevant supply voltage range are guaranteed by design and characterization.)

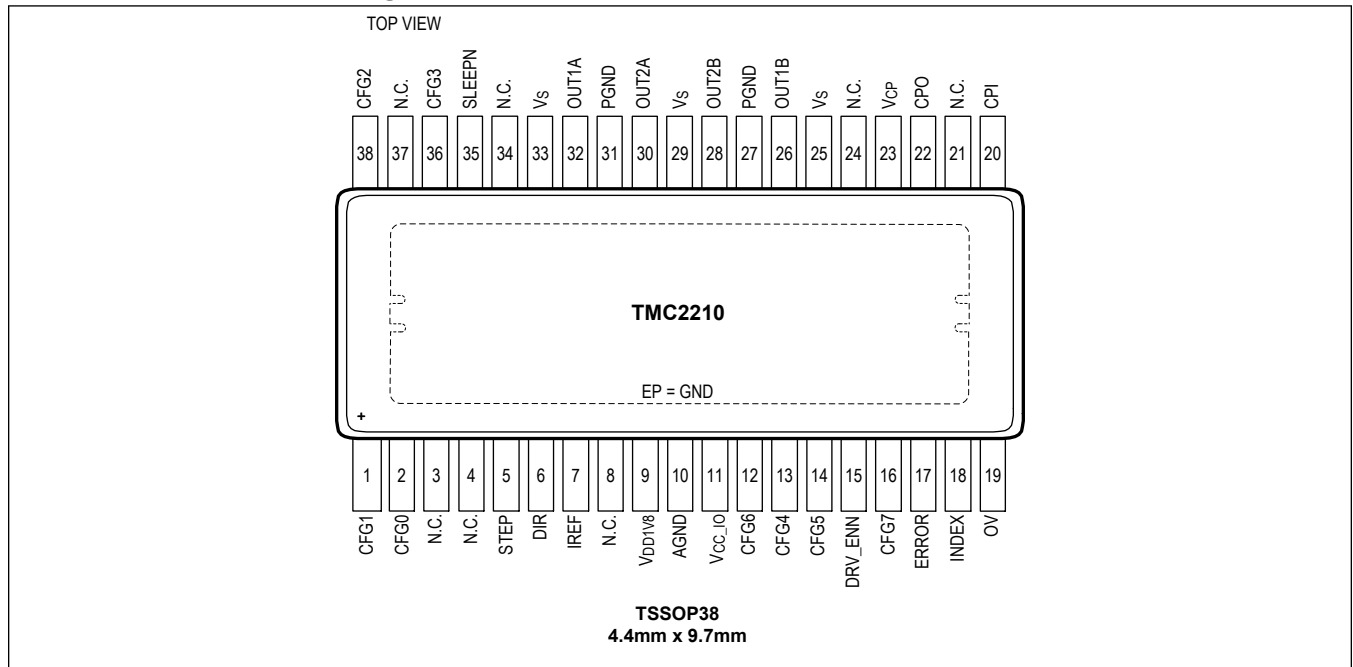
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
STEP High Time	t _{SH}		t _{CLK} + 20			ns
STEP Low Time	t _{SL}		t _{CLK} + 20			ns
DIR to STEP Setup Time	t _{SU}		20			ns
DIR to STEP HoldTime	t _H		20			ns

Pin Configurations

TMC2210 TQFN Pin Configuration



TMC2210 TSSOP Pin Configuration



Pin Description

PIN		NAME	FUNCTION	REF SUPPLY	TYPE
TQFN32	TSSOP38				
4	10	AGND	Analog Ground. Connect to ground plane.		GND
—	27, 31	PGND	Power ground. Connect to ground plane.		GND
17, 20, 21, 24	25, 29, 33	V _S	Motor supply voltage. Provide filtering capacity near pin with shortest loop to GND plane/exposed pad.		Supply
3	9	V _{DD1V8}	Output of internal 1.8V regulator. Attach 2.2μF or larger ceramic capacitor to AGND near to pin for best performance.		Supply
16	23	V _{CP}	Charge pump voltage. Tie to V _S using 1.0μF capacitor. Connect positive end of capacitor close to V _S pin to avoid inductive peaks.		Analog Output
5	11	V _{CC_IO}	Digital IO supply voltage provided from external source to define circuit IO level. Required for proper voltage level settings on output pins.	V _{CC_IO}	Analog Input
15	22	CPO	Charge pump capacitor output.		Analog Output
14	20	CPI	Charge pump capacitor input. Tie to CPO using 22nF 50V capacitor.		Analog Output
31	5	STEP	STEP input.	V _{CC_IO}	Digital Input
32	6	DIR	Direction input.	V _{CC_IO}	Digital Input
1	7	IREF	Analog reference current for current scaling. Provide external resistor to GND.	V _{CC_IO}	Analog Input
9	15	DRV_ENN	Enable input. The power stage becomes switched off (all motor outputs floating) when this pin becomes driven to a high level.	V _{CC_IO}	Digital Input (pullup)
11	17	ERROR	Open-drain error output. Use external pullup resistor. In system reset state, this pin is actively pulled low to indicate reset condition to external controller.	V _{CC_IO}	Digital Output (open drain)
12	18	INDEX	Open drain index pulse output indicating microstep 0 position of coil B.	V _{CC_IO}	Digital Output (open drain)

Pin Description (continued)

PIN		NAME	FUNCTION	REF SUPPLY	TYPE
TQFN32	TSSOP38				
25	35	SLEEPN	<p>Low active power down input / reset input.</p> <p>Apply a continuous low level to bring the device to sleep mode.</p> <p>SLEEPN has an internal pulldown.</p> <p>If not used connect to V_S or V_{CC_IO} (this is a high voltage pin).</p> <p>Once the IC returns from sleep mode/reset the configuration inputs are read and internal registers are set accordingly.</p> <p>Do not toggle while at high motor velocity!</p>	V _S	Analog Input (pull down)
19	28	OUT2B	Motor coil B output 2	V _S	Analog Output
18	26	OUT1B	Motor coil B output 1	V _S	Analog Output
22	30	OUT2A	Motor coil A output 2	V _S	Analog Output
23	32	OUT1A	Motor coil A output 1	V _S	Analog Output
EP	EP	GND	<p>Exposed die pad.</p> <p>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 power stage and internal circuitry.</p>		GND
2, 30	3, 4, 8, 21, 24, 34, 37	N.C.	Not connected, keep open or connect to GND for additional cooling		N.C.
29	2	CFG0	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
28	1	CFG1	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
27	38	CFG2	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
26	36	CFG3	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
7	13	CFG4	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
8	14	CFG5	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
6	12	CFG6	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input
10	16	CFG7	Configuration input, see Table 1 to Table 5 for details on the configuration options	V _{CC_IO}	Digital Input (pull down)

Pin Description (continued)

PIN		NAME	FUNCTION	REF SUPPLY	TYPE
TQFN32	TSSOP38				
13	19	OV	Overvoltage indicator output (open drain) with fixed threshold voltage for maximum voltage rating of the device. Attach external MOSFET with load resistor to limit supply voltage. External pullup resistor required.	V _{CC_IO}	Digital Output (open drain)

Functional Diagrams

TMC2210

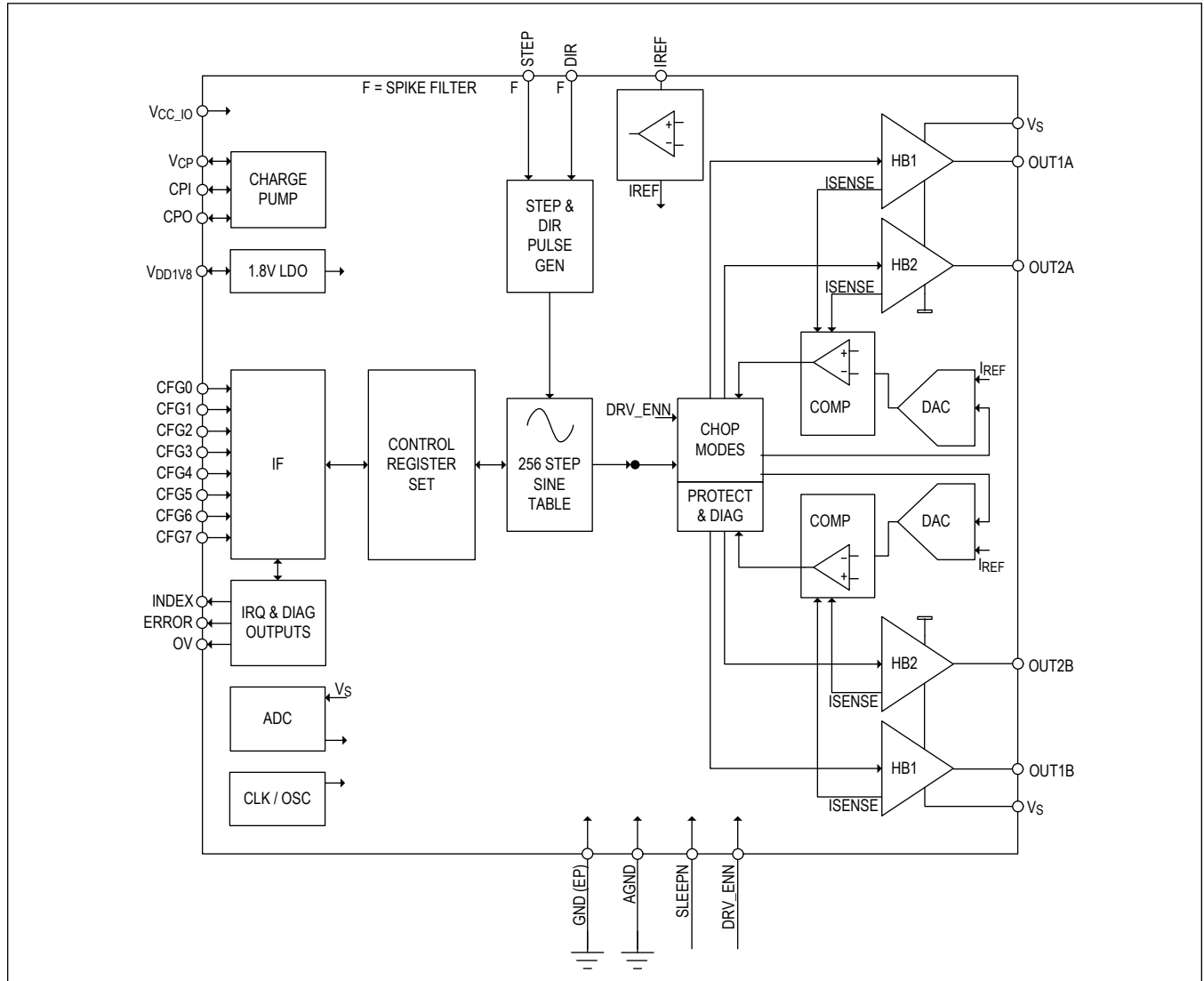


Figure 1. Block Diagram

Detailed Description

Pin-Configurable Step and Direction Driver

The TMC2210 is a step and direction stepper motor driver with pin-configurable settings. Optional feedback signals (ERROR and INDEX) allow error detection and synchronization of motion if required. The TMC2210 implements advanced features exclusive to ADI-Trinamic products. These features contribute toward greater precision, greater energy efficiency, higher reliability, and quieter and smoother motion.

Table 1. TMC2210 Advanced Features

<i>StealthChop2</i>	No-noise, high-precision chopper algorithm for inaudible motion and standstill of the motor.
<i>SpreadCycle</i>	High-precision cycle-by-cycle current control for highest dynamic movements.
<i>MicroPlyer</i>	Microstep interpolator for full 256-microstep smoothness with low-resolution step inputs.

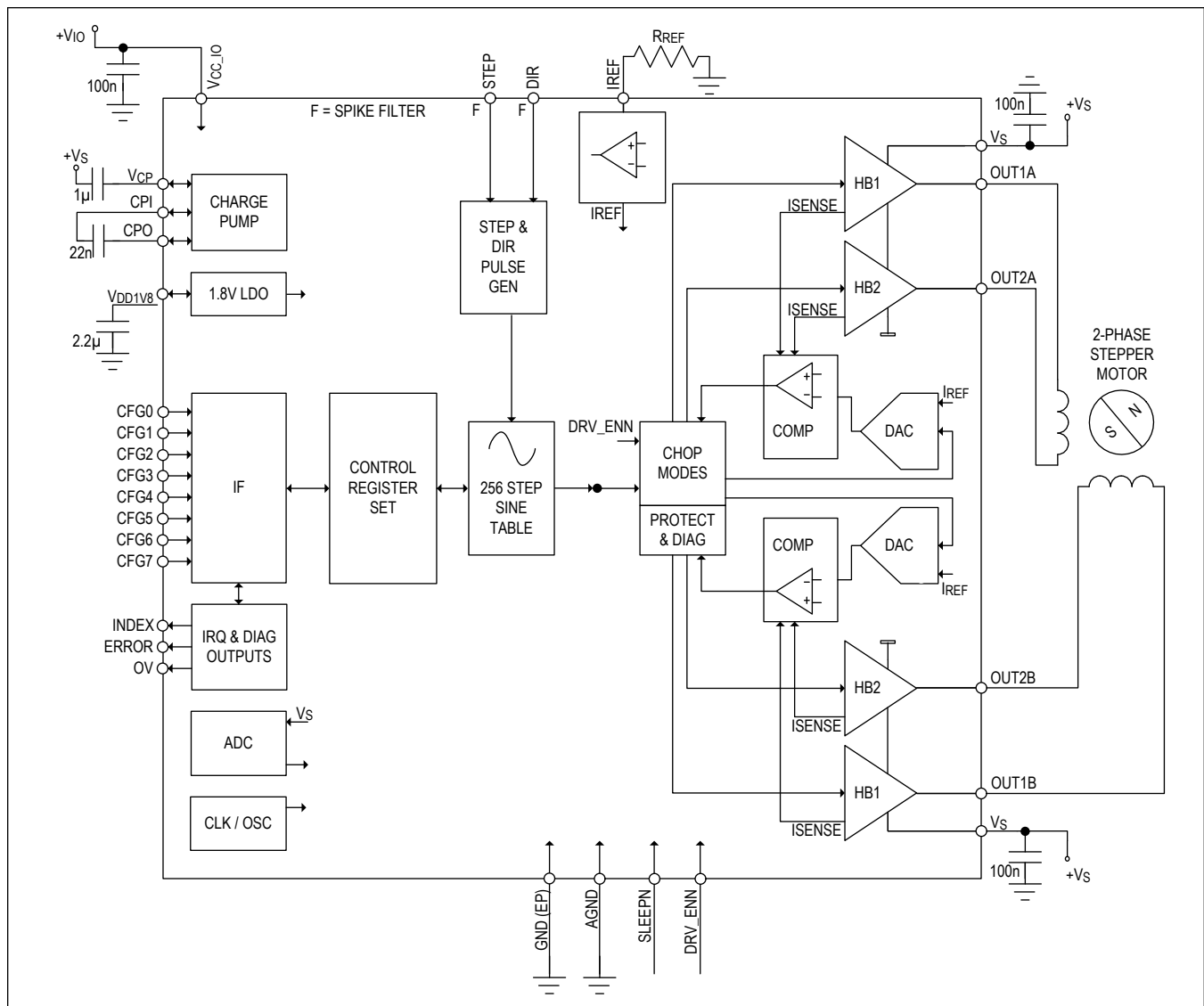


Figure 2. Block Diagram with Typical External Components

Step/Direction 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.

Timing

The figure below shows the timing parameters for the STEP and DIR signals.

Only the rising edges are active and result in a new step. STEP and DIR are sampled and synchronized to the internal system clock. An internal analog filter of approximately 10ns 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 transmitted differentially.

See the [Electrical Characteristics](#) table for the specified timing parameters.

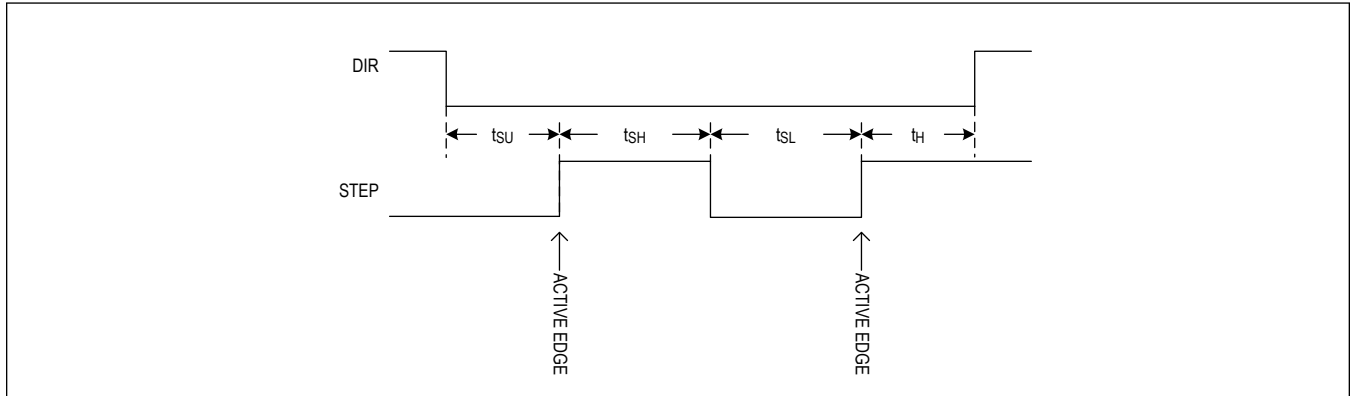


Figure 3. STEP/DIR Signal Timing

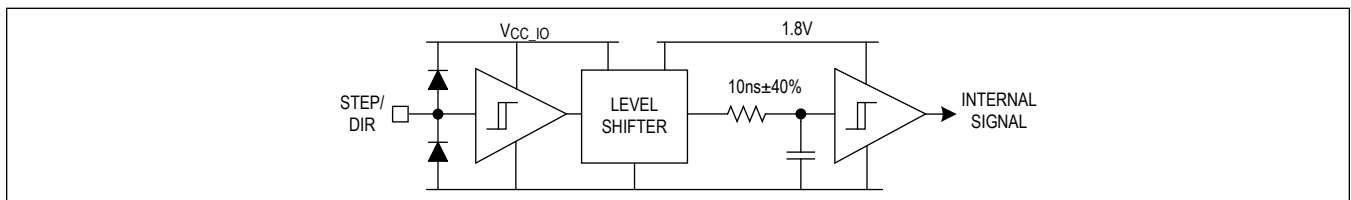


Figure 4. STEP/DIR Signal Internal Input Filter Structure

MicroPlyer Step Interpolator and Standstill Detection

For each active edge on the STEP input, MicroPlyer produces microsteps at a resolution of 256 microsteps per fullstep. It interpolates the time in between two step impulses at the STEP input based on the last step interval. This way, from 4 microsteps (64 microstep input to 256 microstep interpolation) up to 32 microsteps (8 microstep input to 256 microstep interpolation) are driven for a single-step pulse. This enables seamless drop-in microstepping capability without the requirement of adapting the step source.

The TMC2210 allows configuration of four different input resolutions: 8, 16, 32, and 64 microsteps. MicroPlyer is always enabled in the TMC2210.

The step frequency for the interpolation to 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. A lower step rate results in the standstill detection and condition. When a standstill is detected, the driver automatically switches the motor to holding current *I_{HOLD}*.

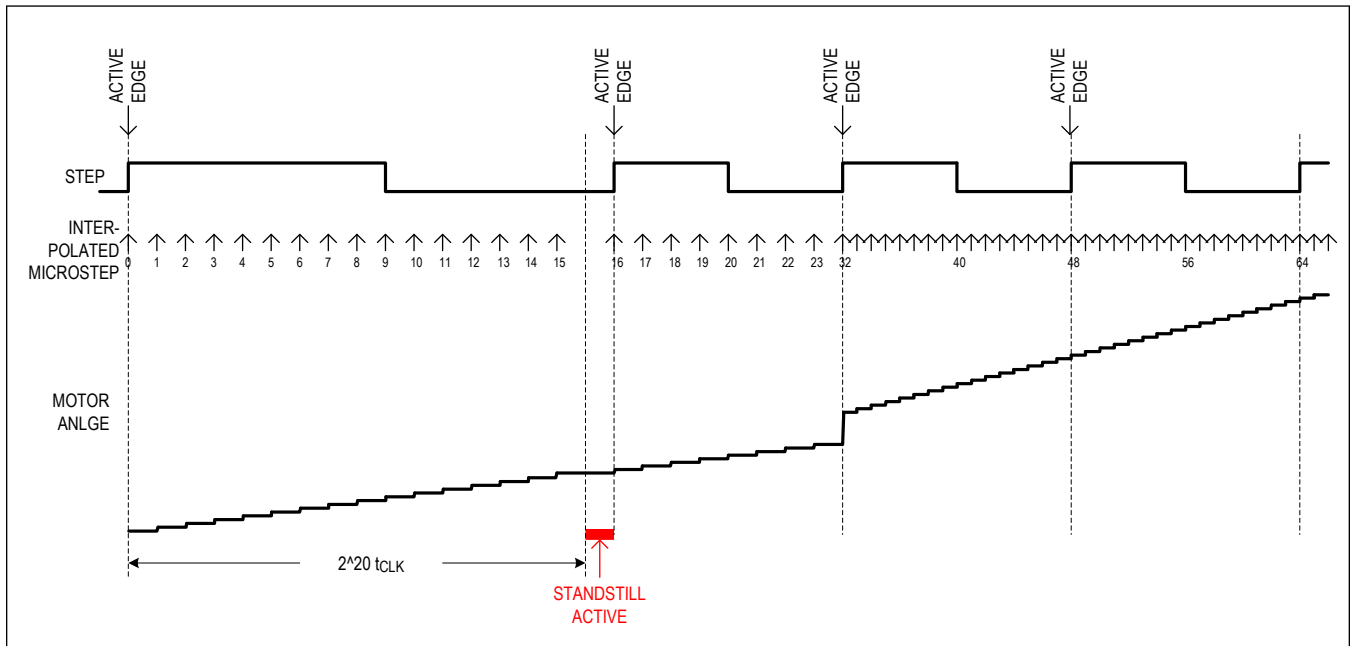


Figure 5. MicroPlyer Microstep Interpolation with Rising STEP Frequency (Example: 16 to 256)

In the figure above, the first STEP cycle is long enough to set the internal standstill bit *stst*. This internal 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.

Pin Configuration Options

The following settings can be adjusted using the CFGx pins:

Table 2. Microstep Resolution Configuration for the Step Input

CFG0/CFG1: CONFIGURATION OF MICROSTEP RESOLUTION FOR STEP INPUT		
CFG1	CFG0	MICROSTEP SETTING
GND	GND	8 microsteps
GND	V _{CC_IO}	16 microsteps
V _{CC_IO}	GND	32 microsteps
V _{CC_IO}	V _{CC_IO}	64 microsteps

Hint: A change during motor rotation will lead to a velocity jerk unless the step frequency is adapted at the same moment.

Table 3. Run Current (IRUN) Configuration

CFG3/CFG2: CONFIGURATION OF RUN CURRENT IRUN (ALONG WITH IREF RESISTOR), DO NOT CHANGE DURING OPERATION		
CFG3	CFG2	CURRENT RANGE SETTING
GND	GND	Current Scaling = 1A peak
GND	V _{CC_IO}	Current Scaling = 2A peak
V _{CC_IO}	GND	Current Scaling = 3A peak
V _{CC_IO}	V _{CC_IO}	not used (3A peak)

Table 4. Digital Current Scale Configuration

CFG4: DIGITAL CURRENT SCALE (MAY BE CHANGED DURING OPERATION)	
CFG4	CURRENT SCALE
GND	I = 75% of full scale current IRUN
V _{CC_IO}	I = 100% of full scale current IRUN

Table 5. Chopper Mode Selection

CFG5: SELECTION OF CHOPPER MODE	
CFG5	CHOPPER MODE
GND	SpreadCycle operation
V _{CC_IO}	StealthChop2 operation

Hint: First operation with StealthChop2 can only be enabled during standstill to allow for tuning of the integrated current scaling algorithm.

Table 6. Hold Current (IHOLD) Reduction Configuration

CFG7/CFG6: CONFIGURATION OF HOLD CURRENT REDUCTION		
CFG7	CFG6	HOLD CURRENT REDUCTION
GND	GND	No hold current reduction. IHOLD = IRUN
GND	V _{CC_IO}	Reduction to 50%. IHOLD = 1/2 IRUN
V _{CC_IO}	GND	Reduction to 25%. IHOLD = 1/4 IRUN
V _{CC_IO}	V _{CC_IO}	Reduction to 12.5%. IHOLD = 1/8 IRUN

StealthChop2

StealthChop2 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, StealthChop2 operated stepper motor applications are very suitable for indoor or home use. The motor operates absolutely free of vibration at low velocities. With StealthChop2, the motor current is applied by driving a certain effective voltage into the coil, using a voltage mode PWM. With the enhanced StealthChop2, the driver automatically adapts to the application for best performance. No more configuration is required.

In order to match the motor current to a certain level, the effective PWM voltage becomes 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 the actual level of the supply voltage. The StealthChop2 PWM frequency depends on the internal clock frequency.

Be sure to allow the motor to rest for at least 100ms before starting a motion using StealthChop2. This allows the current regulation to set the initial motor current.

For high-velocity use cases, SpreadCycle should be considered in combination with StealthChop2 by switching between the two modes using the pin CFG5. When switching between both modes, a small jerk might be visible because of a phase shift between voltage and current.

Attention: A motor stall, or abrupt stop of the motion during operation in StealthChop2 can trigger an overcurrent condition. Depending on the previous motor velocity, and on the coil resistance of the motor, it significantly increases motor current for a time of 10ms to 100ms. With low velocities, where the back EMF is just a fraction of the supply voltage, there is no danger of triggering the short detection.

Table 7. StealthChop2 PWM Frequency

CLOCK FREQUENCY f _{CLK}	PWM FREQUENCY f _{PWM} = 2/1024 f _{CLK}
12.5MHz (internal)	24.4kHz

SpreadCycle

While StealthChop2 is a voltage mode PWM-controlled chopper, SpreadCycle is a cycle-by-cycle current control chopper. Therefore, it can react extremely fast to changes in motor velocity or motor load. The currents through both motor coils are controlled using dedicated chopper circuits. The chopper circuits work independently of each other. In the following figure, the different chopper phases are shown. The dedicated sense resistor in the image below is only used for better explanation. The TMC2210 comes with fully internal current sensing.

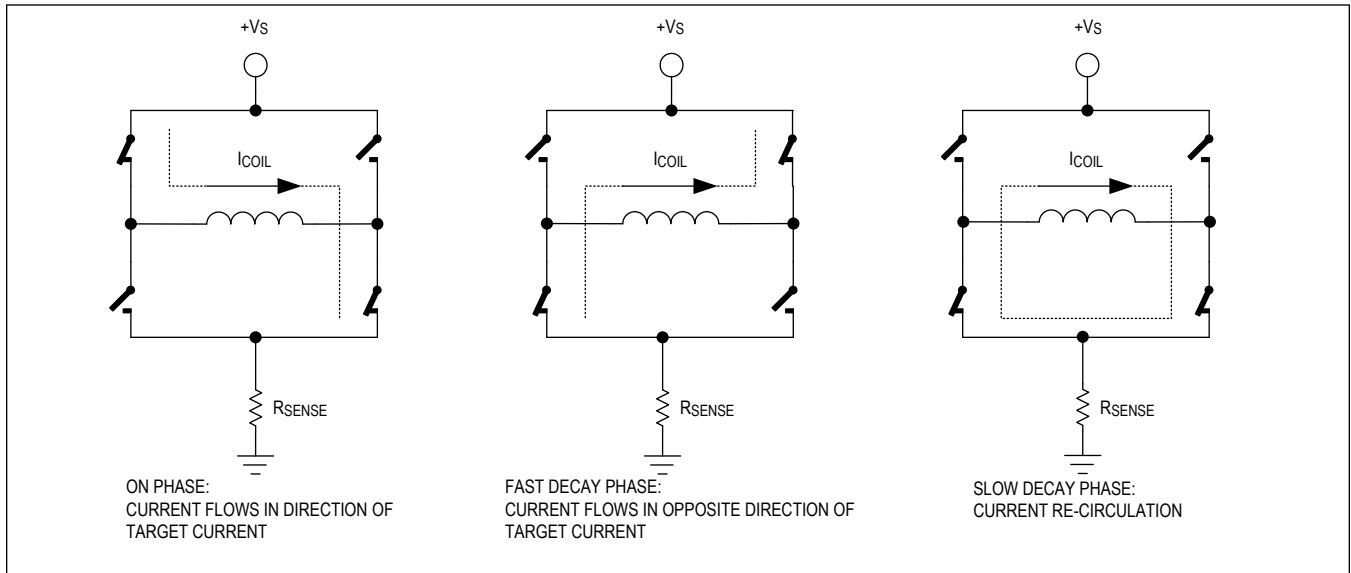


Figure 6. SpreadCycle Chopper Decay Phases

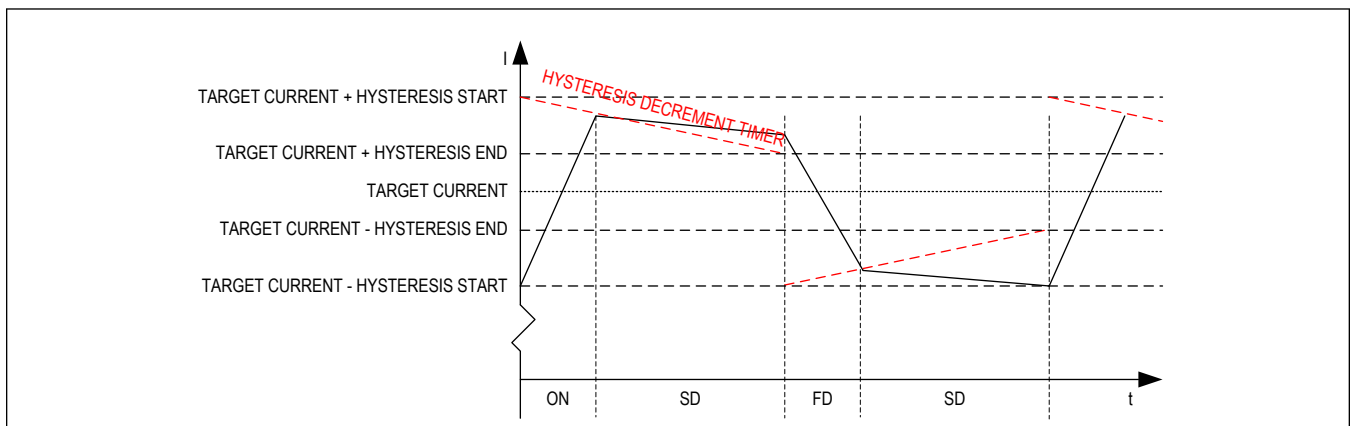


Figure 7. Phase Current Profile during one SpreadCycle Chopper Cycle

Although the current could be regulated using only on phases (ON) and fast decay (FD) phase, insertion of the slow decay (SD) phase is important to reduce electrical losses and current ripple in the motor. The current comparator can measure coil current during phases when the current flows through exactly one low-side transistor, but not during the SD phase, so the SD phase is terminated by a timer. The on phase is terminated by the comparator when the current through the coil reaches the target current plus some hysteresis. The FD phase may be terminated by either the comparator or another timer.

When the coil current is switched, spikes in the $R_{DS(ON)}$ -based current measurement occur due to charging and

discharging parasitic capacitance.

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 high-performance chopper algorithm called SpreadCycle cycles through four phases: on, slow decay, fast decay, and a second slow decay.

Table 8. SpreadCycle Parameters

PARAMETER	DESCRIPTION	SETTING
<i>TOFF</i>	The slow decay time (<i>off time</i>) is set to 120 t_{CLK} .	120 t_{CLK}
<i>TBL</i>	The comparator <i>blank time</i> safely covers the switching event and the duration of the ringing on the $R_{DS(ON)}$ measurement.	36 t_{CLK}

Integrated Current Sense

Non-dissipative current sensing is integrated in the TMC2210 (ICS). This feature eliminates the bulky external power resistors, which are normally required with external current sensing. The ICS results in a dramatic space and power saving compared with mainstream applications based on the external sense resistor. For optimum performance, the ICS individually measures $R_{DS(ON)}$ for each of the power MOSFETs taking into account individual MOSFET temperature to yield the best results.

Setting the Full Scale Current Range

The full scale current I_{FS} is a peak current setting. It is selected with an external reference resistor and the two configuration pins CFG2 and CFG3 (see also Table 2 in the [Pin Configuration Options](#) section).

Three different full-scale current ranges can be configured through the pins with the same reference resistor to adapt to different motor sizes and applications. This is needed to benefit from the best possible current control resolution.

Connect a reference resistor R_{REF} from IREF to GND. Together with pins CFG3 and CFG2, the full scale current range I_{FS} is set based on the external resistor .

The equation below shows the full-scale current I_{FS} as a function of the R_{REF} shunt resistor connected to pin IREF and the configuration pin setting. The proportionality constant K_{IFS} is defined by the CFG2 and CFG3 setting. The external resistor R_{REF} can range between 12k Ω and 60k Ω .

$$I_{FS} = K_{IFS}(KV) / R_{REF}(k\Omega)$$

Table 9. I_{FS} Full Scale Current Range Settings (Example for $R_{REF} = 12k\Omega$)

PIN CONFIG IN STANDALONE MODE		K_{IFS} (A x k Ω)	MAX FS SETTING	TYPICAL $R_{DS(ON)}$ (HS + LS)	NOTES
CFG3	CFG2				
1	1	36	3A	0.23 Ω	Optimized efficiency for motors and applications rated up to 2.1A rms.
1	0	36	3A	0.23 Ω	Optimized efficiency for motors and applications rated up to 2.1A rms.
0	1	24	2A	0.27 Ω	Optimized efficiency for motors and applications rated up to 1.4A rms.
0	0	11.75	1A	0.40 Ω	Optimized efficiency for motors and applications rated up to 0.7A rms.

The following table is a matrix of different reference resistor values (at pin IREF) versus the different pin configurations for the full-scale current. The resulting maximum RMS current is given in each cell.

Table 10. IFS Full Scale RMS Current in Ampere (A RMS) based on CFG2/CFG3 Pin Settings and different R_{REF}

R _{REF} (kΩ)	MAX FULL SCALE CURRENT (A RMS) BASED ON CFG PIN SETTING AND K _{IFS} (A x kΩ)			
	CFG3/CFG2 = 1/1	CFG3/CFG2 = 1/0	CFG3/CFG2 = 0/1	CFG3/CFG2 = 0/0
	K _{IFS} = 36	K _{IFS} = 36	K _{IFS} = 24	K _{IFS} = 11.75
12	2,12	2,12	1,41	0,69
15	1,70	1,70	1,13	0,55
18	1,41	1,41	0,94	0,46
22	1,16	1,16	0,77	0,38
27	0,94	0,94	0,63	0,31
33	0,77	0,77	0,51	0,25
39	0,65	0,65	0,44	0,21
47	0,54	0,54	0,36	0,18
56	0,45	0,45	0,30	0,15

Additional options to scale and adapt the motor run and hold current is the digital current scale configuration and hold current reduction configuration using the configuration pins.

See also Table 3 and Table 5 in the [Pin Configuration Options](#) section.

Diagnostic Outputs

Operation with an external motion controller often requires quick reaction to certain states of the stepper motor driver. Therefore, the diagnostic outputs ERROR and INDEX supply a fixed set of real-time information complementing the STEP/DIR interface.

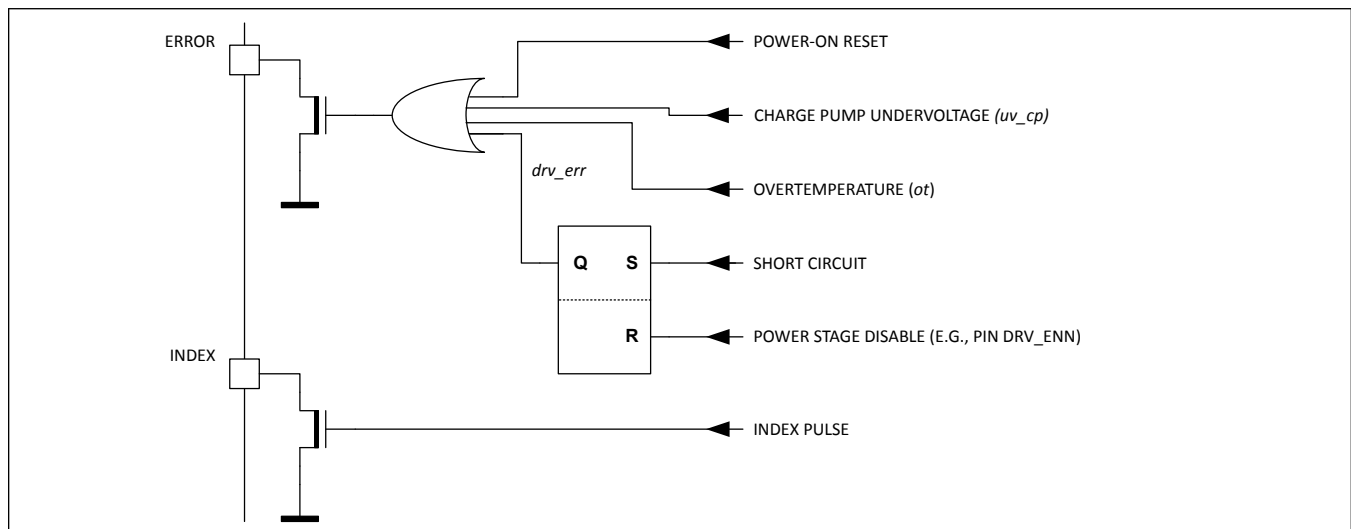


Figure 8. Diagnostic Outputs INDEX and ERROR

ERROR shows any driver error that prevents the chip from operating. This is an open-drain output. In order to determine a reset of the driver, ERROR always shows a power-on reset condition by pulling low during a reset condition.

An active INDEX output signals that the cosine curve of motor coil B is at its positive zero transition. The duration of the index pulse corresponds to the duration of the microstep. The index output allows precise detection of the microstep position within one electrical wave, i.e., within a range of four fullsteps. With this, homing accuracy and reproducibility can be enhanced to microstep accuracy, even when using an inexpensive home switch. Thereby, the INDEX signal is a low active open-drain output. The active pulse is a low pulse.

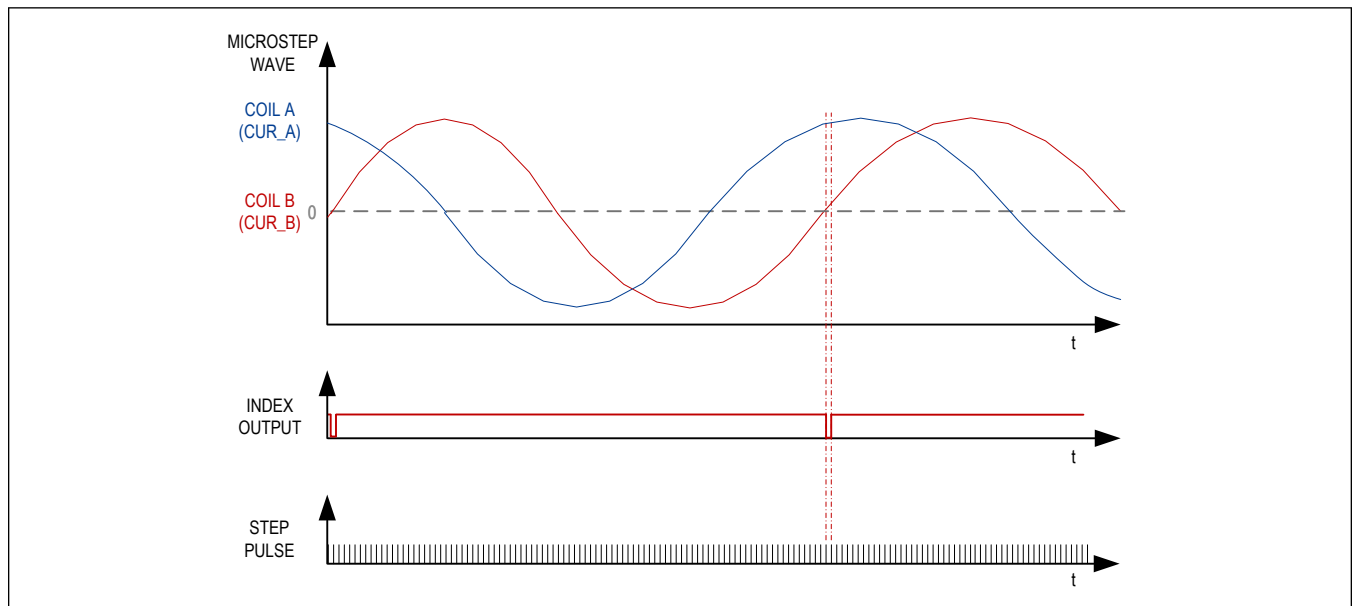


Figure 9. Index Signal Pulse at Positive Zero Transition of the Coil B Microstep Wave

External Reset, Sleep Mode, and Bridge Three State

The reset and sleep mode are controlled with the SLEEPN pin.

A short pulse on SLEEPN with a duration $>30\mu\text{s}$ results in a chip reset.

Very short pulses $<30\mu\text{s}$ are filtered out and do not have an effect on the operation.

If SLEEPN is kept at GND the IC goes into low power standby state (sleep mode). All internal supplies and bridge drivers are switched off.

After power-up or leaving sleep mode and reset condition the configuration pins are read and internal registers set accordingly.

The wake-up time is given in the EC table.

If not used connect to V_S or V_{CC_IO} (this is a high voltage pin).

Driving the DRV_ENN pin high, the bridge drivers of TMC2210 can be disabled and the motor is freewheeling.

Be careful using these pins during high motor velocity as energy fed back from the motor might damage the chip!

Protections and Driver Diagnostics

Overcurrent Protection

The overcurrent protection (OCP) protects the device against short-circuits to the rails (supply voltage and ground) and between the outputs (OUT1A, OUT2A, OUT1B, OUT2B).

The OCP threshold depends on the selected full-scale current range (selected by configuration pins)/see the [Electrical Characteristics](#) table for the respective threshold values.

If the output current is greater than the OCP threshold for longer than the deglitch time (blanking time), then an OCP event is detected.

When an OCP event is detected, the H-bridges are immediately disabled.

The short protection is tried three times before the ERROR output is set and the bridges become disabled.

To re-enable the H-bridges, DRV_ENN pin must be cycled.

Thermal Protection and Shutdown

The TMC2210 has an internal thermal protection.

If the local die temperature exceeds 165°C (typical value), the driver is three-stated until the junction temperature drops below ca. 145°C (typical value). After that, the driver is re-enabled.

As long as the overtemperature condition persists, the ERROR output is set high.

Heat is mainly generated by the motor driver stages, and, at increased voltage, by the internal voltage regulator. Most critical situations, where the driver MOSFETs could be overheated, are avoided when enabling the short to GND protection. The thermal shutdown is an emergency measure and temperature rising to the shutdown level should be prevented by design.

Overvoltage Protection and Pin OV

A stepper motor application can generate significant overvoltage, especially when the motor becomes quickly decelerated from a high velocity, or when the motor stalls.

This voltage becomes fed back to the supply rails by the driver output stage.

For typical NEMA17 or larger motors, and also for smaller motors with sufficient flywheel mass, the energy fed back can be substantial, so that the power capacitors and circuit consumption are not sufficient to keep the supply within its limits.

To protect the driver as well as connected circuitry, the TMC2210 has an overvoltage detection and protection mechanism.

The OV output allows attaching an NPN or MOSFET with a power resistor (brake resistor) to dump the excess energy into the resistor.

The transistor is switched with approximately 3kHz to 4kHz (depending on the clock frequency) to keep the supply within the limits.

Very fast transients cannot be captured with this overvoltage protection mechanism.

The supply voltage is permanently monitored with the internal ADC (except while in sleep mode).

The upper threshold level for the supply voltage is set to 38V and is compared against the actual measured value of the supply voltage.

The OV output pin shows the actual state of the overvoltage monitor.

As soon as and as long as the supply voltage is greater or equal to 38V the OV output pin is active (pulled low).

The OV output pin is an open-drain pin. The following diagram shows an example brake chopper circuit:

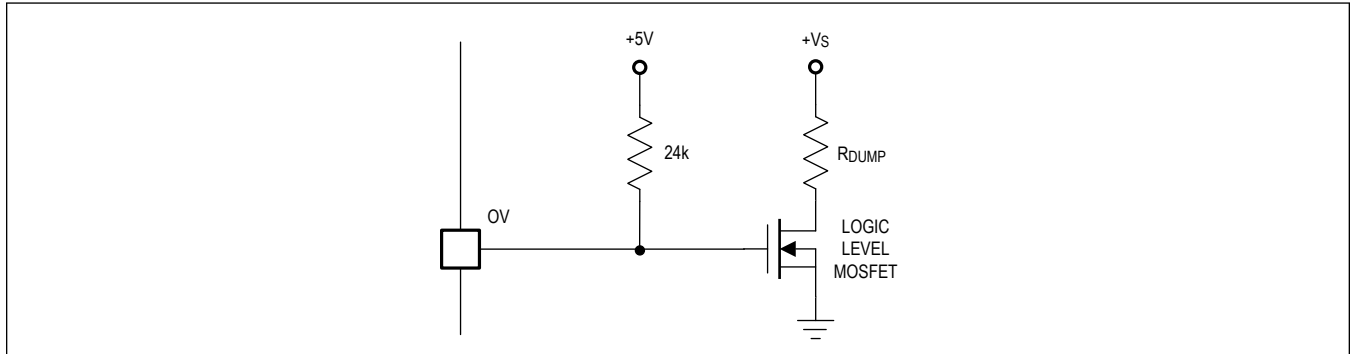


Figure 10. Brake Chopper Circuit Example

Short to GND Protection

The TMC2210 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 becomes switched off and the error condition is indicated at the ERROR pin. In order to restart the motor, the user must disable and re-enable the driver by using the DRV_ENN pin. It should be noted, that the short to GND 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.

Undervoltage Lockout Protection

The TMC2210 features a UVLO protection for V_S , V_{CC_IO} , and the charge pump.

- UVLO on V_S is set at 4.5V (max)
- UVLO condition on V_{CC_IO} is triggered below 1.95V (max).
- UVLO condition on the charge pump is triggered in case of an error condition of the charge pump, e.g., due to a wrong capacitor value.

All UVLO condition results in a chip reset and ERROR pin is active low (open drain).

ESD Protections

The TMC2210 has internal ESD protection on every pin.

The motor phase output pins are protected up to 8kV HBM in the application when using a bypass capacitor of at least 1uF on the positive voltage supply (V_S Pin).

Anyhow, this is no protection against hot plugging of a motor. See the [Typical Application Circuits](#) section for additional external protection options.

Typical Application Circuits

Standard Application Circuit

The standard application circuit uses a minimum set of additional components. Use low ESR electrolytic capacitors for filtering the power supply. The capacitors need to cope with the current ripple cause by chopper operation. A minimum capacity of 100 μ F at V_S is recommended for best performance. Current ripple in the supply capacitors also depends on the power supply internal resistance and cable length. V_{CC_IO} must be supplied from an external source, e.g., a low-drop 3.3V regulator.

Place all filter capacitors as close as possible to the related IC pins. Use a solid common ground plane for all GND connections. Connect V_{DD1V8} filtering capacitor directly to the V_{DD1V8} pin.

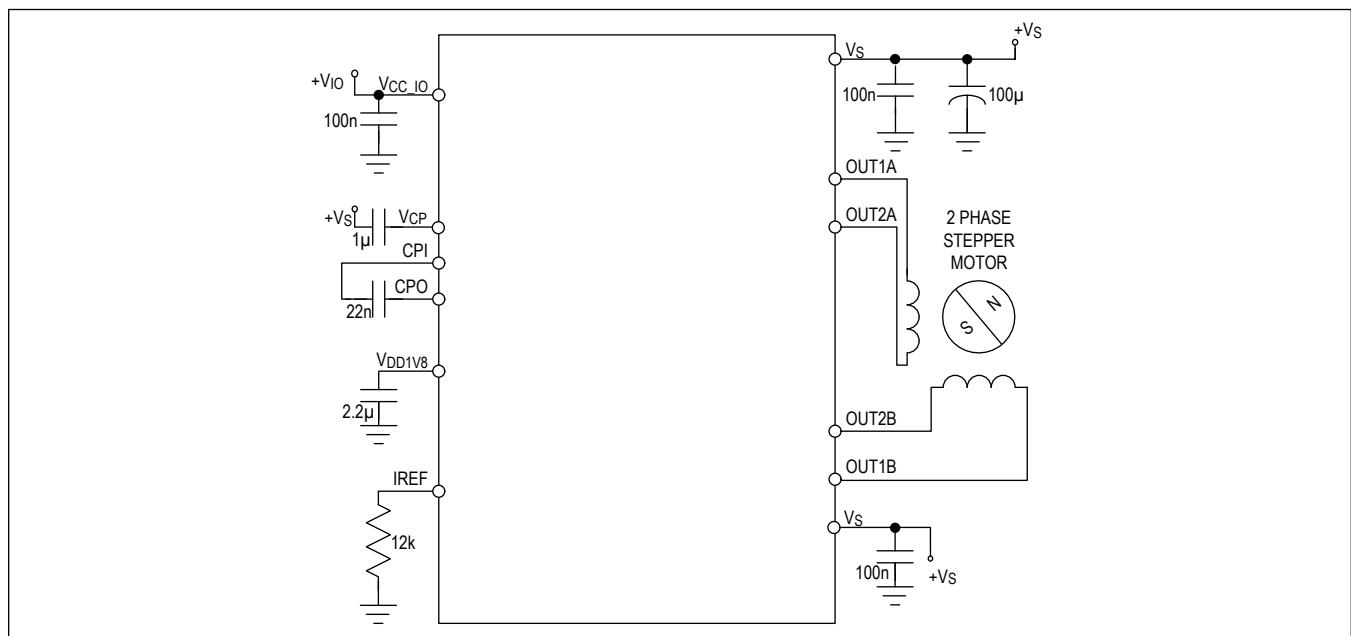


Figure 11. Standard Application Circuit

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 heats up the PCB cooling infrastructure also, 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 to the *Thermal Characteristics* and the *Layout Examples* sections of the evaluation kit as well.

As a thumb rule, thermal properties of the PCB design may become critical at or above 1.5A RMS motor current for increased periods of time. Note that the 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.

Driver Protection and EME Circuitry

Some applications have to cope with ESD events caused by motor operation or external influence. Despite ESD

Typical Application Circuits (continued)

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 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.

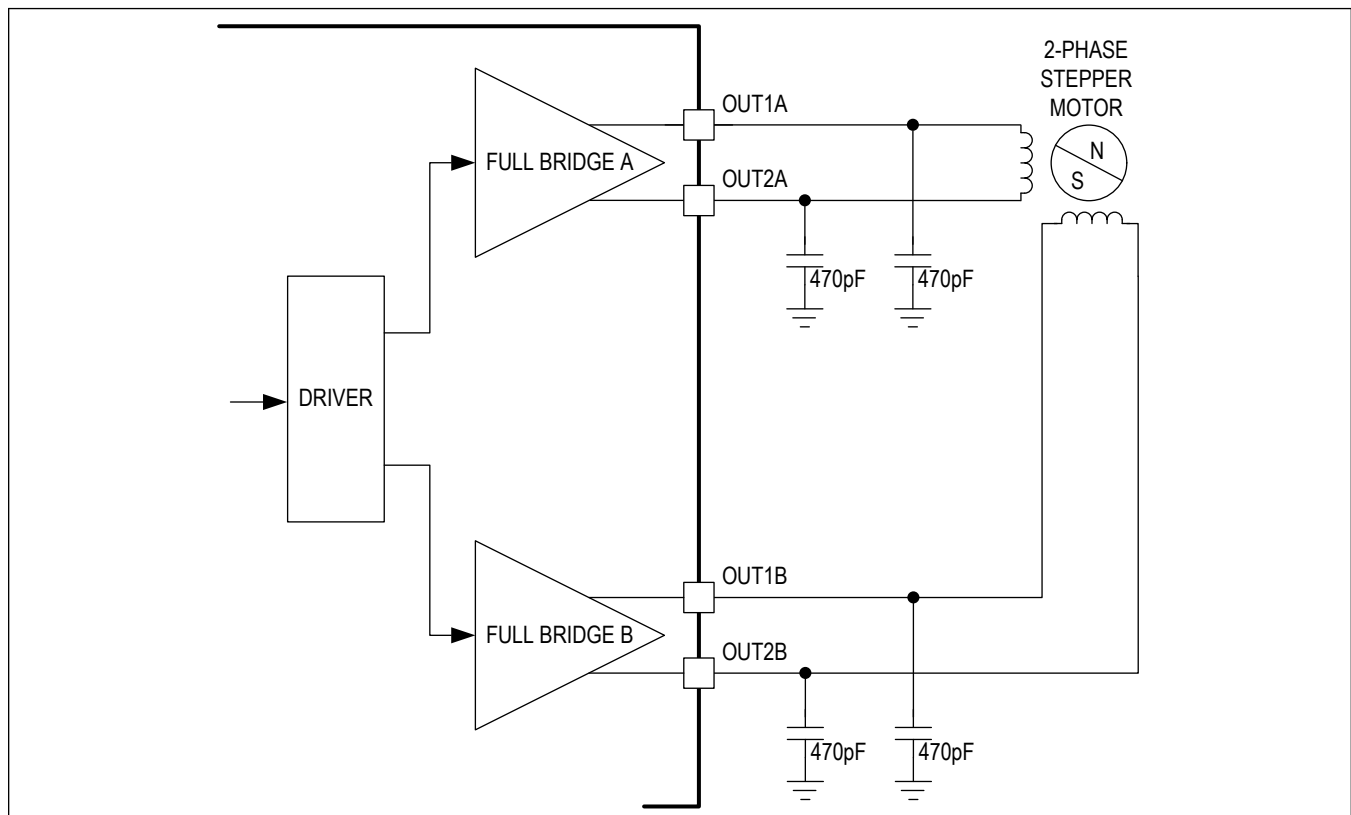


Figure 12. Simple ESD Enhancement

A more elaborate scheme uses LC filters to decouple the driver outputs from the motor connector. Varistors V1 and V2 in between of the coil terminals eliminate coil overvoltage caused by live plugging. Optionally protect all outputs by a varistor (V1A, V1B, V2A, V2B) against the ESD voltage. Fit the varistors to the supply voltage rating. The SMD inductivities conduct full motor coil current and need to be selected accordingly.

Typical Application Circuits (continued)

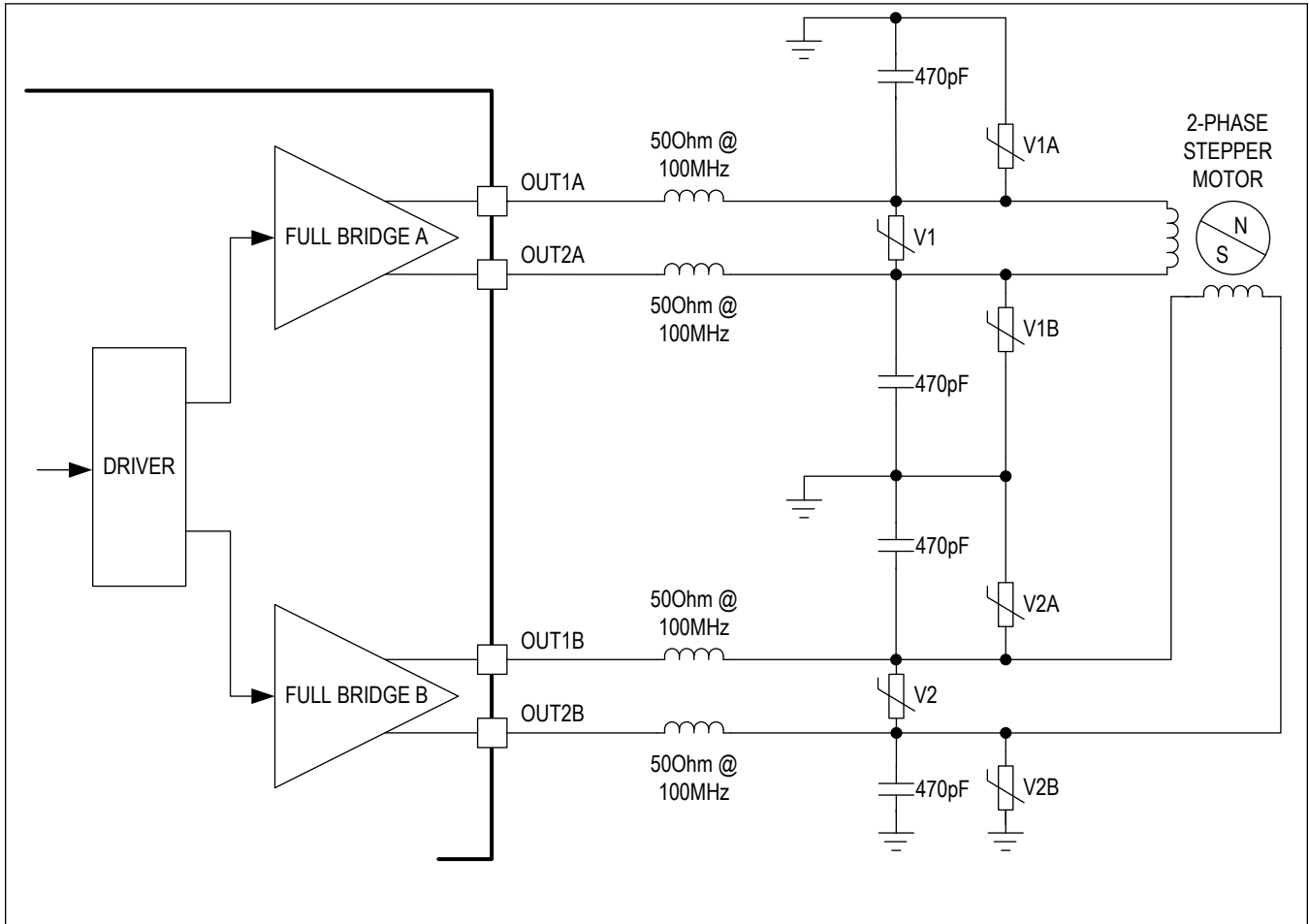


Figure 13. Extended Motor Output Protection

Ordering Information

PART NUMBER	TEMPERATURE RANGE	PIN-PACKAGE
TMC2210ATJ+	-40°C to +125°C	32 TQFN - 5mm x 5mm
TMC2210ATJ+T	-40°C to +125°C	32 TQFN - 5mm x 5mm
TMC2210AUU+*	-40°C to +125°C	38 TSSOP-EP 4.4mm x 9.7mm
TMC2210AUU+T*	-40°C to +125°C	38 TSSOP-EP 4.4mm x 9.7mm

* Future product—contact factory for availability.

+ Denotes a lead(Pb)-free/RoHS-compliant package.

T Denotes tape-and-reel.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/22	Release for Market Intro	—