TMC 236 – DATA SHEET

High Current Microstep Stepper Motor Driver with protection / diagnosis and SPI Interface

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Features

The TMC236 is a dual full bridge driver IC for bipolar stepper motor control applications. It is realized in a HVCMOS technology combined with Low-RDS-ON high efficiency MOSFETs (pat. fi.). The TMC236 gives the choice to operate at high temperature or at high current of up to 1500 mA. Its low current consumption and high efficiency together with the miniature package make it a perfect solution for embedded motion control and for battery powered devices. Internal DACs allow microstepping as well as smart current control. The device can be controlled by a serial interface (SPI™[i]) or by analog / digital input signals. Short circuit, temperature and undervoltage protection is integrated.

- Control via SPI with easy-to-use 12 bit protocol or external analog / digital signals
- Short circuit protection integrated
- Status flags for overcurrent, open load, over temperature, temperature pre-warning, undervoltage
- Integrated 4 bit DACs allow up to 16 times microstepping via SPI, any resolution via analog control
- Mixed decay feature for smooth motor operation
- Slope control user programmable to reduce electromagnetic emissions
- Chopper frequency programmable via a single capacitor or external clock
- Current control allows cool motor and driver operation
- Internal open load detector
- 7V to 28.5V motor supply voltage
- Up to 1500mA output current and more than 800mA at 105°C
- 3.3V or 5V operation for digital part
- Low power consumption via low RDS-ON power stage
- Standby and shutdown mode available

Life support policy

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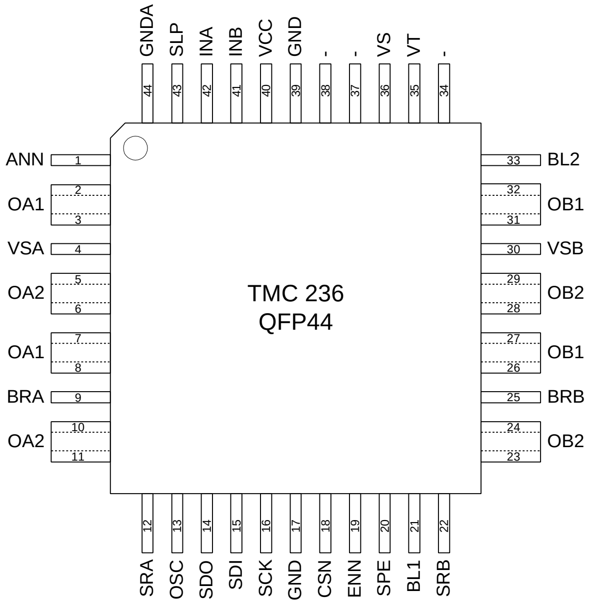
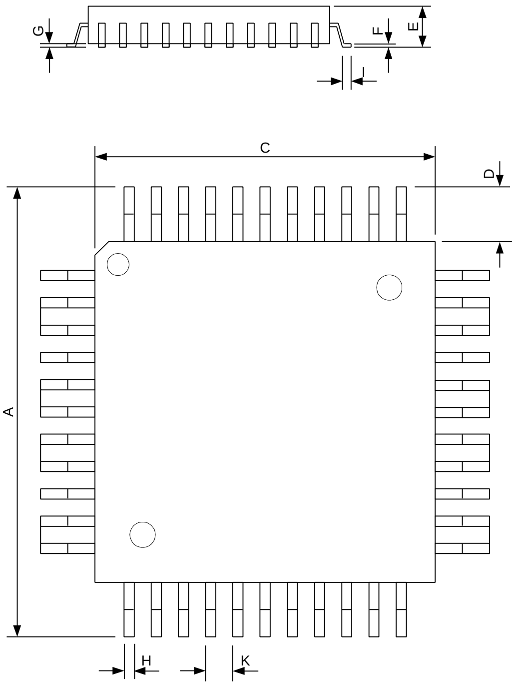
Pinning



Package codes

Package	Temperature range	Code/marking
PQFP 44	industrial to be announced	TMC236-PI
PQFP 44	automotive	TMC236-PA

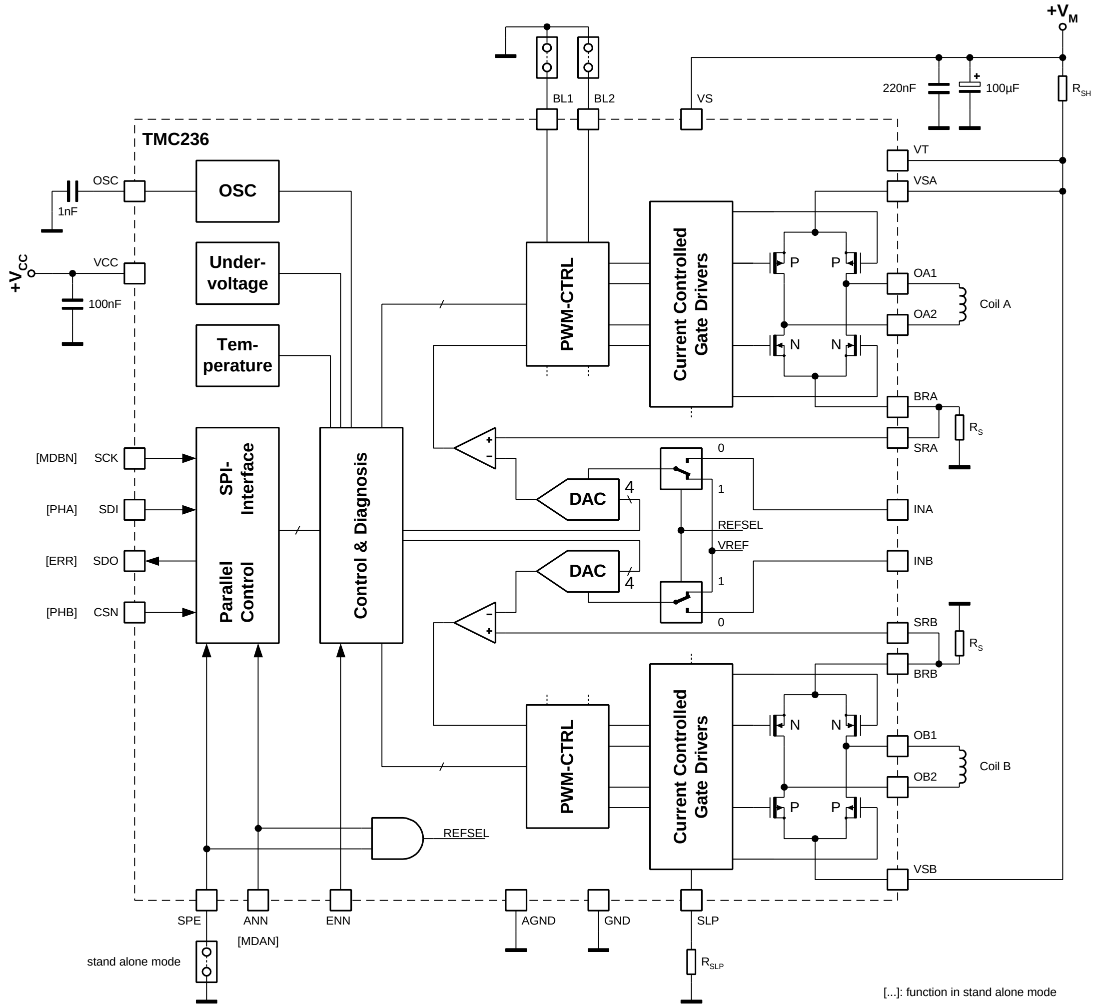
PQFP44 Dimensions



REF	MIN.	MAX.
A	12	
C	10	
D	1	
E	-	1.6
F	0.09	0.2
G	0.05	0.15
H	0.30	0.45
I	0.45	0.75
K	0.8	

All dimensions are in mm.

Application circuit / block diagram



Pin functions

Pin	Function	Pin	Function
VS	Motor supply voltage	VT	Short to GND detection comparator – connect to VS if not used
VCC	3.0-5.5V supply voltage for analog and logic circuits	GND	Power ground
AGND	Analog ground (Reference for SRA, SRB, OSC, SLP, INA, INB)	OSC	Oscillator capacitor or external clock input for chopper
INA	Analog current control phase A	INB	Analog current control input phase B
SCK	Clock input of serial interface	SDI	Data input of serial interface
SDO	Data output of serial interface	CSN	Chip select input of serial interface
ENN	Device enable (low active), high causes a total shutdown of the device and resets all registers	SPE	Enable SPI mode (high active). Tie to GND for non-SPI applications
ANN	Enable analog current control (low active): Enables INA and INB for output current control	SLP	Slope control resistor. Tie to GND for fastest slope
BL1, BL2	Digital blank time select	SRA, SRB	Bridge A/B current sense resistor input
OA1, OA2	Output of full-bridge A	OB1, OB2	Output of full-bridge B
VSA, VSB	Supply voltage for bridge A/B	BRA, BRB	Bridge A/B sense resistor

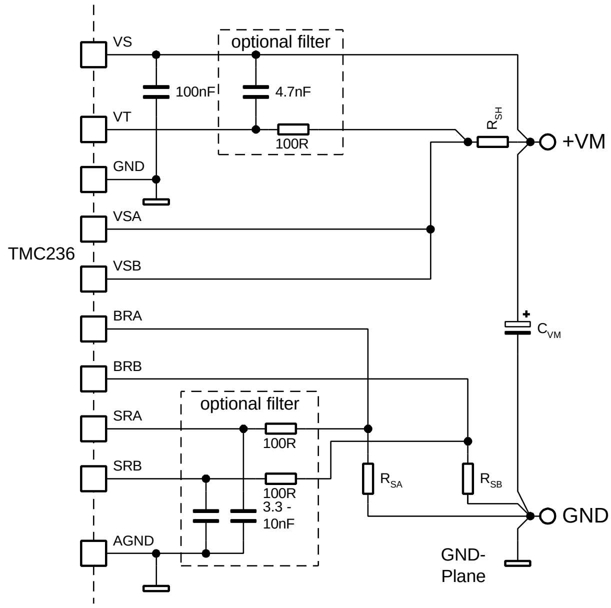
Layout considerations

For optimal operation of the circuit a careful board layout is important, because of the combination of high current chopper operation coupled with high accuracy threshold comparators. Please pay special attention to a massive grounding. Depending on the required motor current, either a single massive ground plane or a ground plane plus star connection of the power traces may be used. The schematic shows how the high current paths can be routed separately, so that the chopper current does not flow through the system's GND-plane. Tie the TMC236's AGND and GND to the GND plane. Additionally, use enough filtering capacitors located near to the board's power supply input and small ceramic capacitors near to the power supply connections of the TMC236. Use low inductance sense resistors, or add a ceramic capacitor in parallel to each resistor to avoid high voltage spikes. In some applications it may become necessary to introduce additional RC-filtering into the VT and SRA / SRB line, as shown in the schematic, to prevent spikes from triggering the short circuit protection or the chopper comparator.

Be sure to connect all pins of the LQFP package for each of the double/quad output pins externally. Each two of these output pins may be fused to a single wide pin depending on the version of the package (as shown in the drawing). These pins are used as cooling fin for one of the eight integrated output power transistors. Use massive motor current traces on all these pins and multiple vias, if the output trace is changed to a different layer near the package.

A symmetrical layout on all of the OA and OB pins is required, to ensure proper heat dissipation on all output transistors. Otherwise proper function of the thermal protection can not be guaranteed!

A multi-layer PCB shows superior thermal performance, because it allows usage of a massive GND plane, which will act as a heat spreader. The heat will be coupled vertically from the output traces to the GND plane, since vertical heat distribution in PCBs is quite effective. Heat dissipation can be improved by attaching a heat sink to the package directly.



SPI-Telegram

The SPI data word sets the current and polarity for both coils. By applying consecutive values, describing a sine and a cosine wave, the motor can be driven in microsteps. Every microstep is initiated by its own telegram. Please refer to the description of the analog mode for details on the waveforms required.

Serial data word transmitted to TMC236

(MSB transmitted first)

Bit	Name	Function	Remark
11	MDA	mixed decay enable phase A	“1” = mixed decay
10	CA3	current bridge A.3	MSB
9	CA2	current bridge A.2	
8	CA1	current bridge A.1	
7	CA0	current bridge A.0	LSB
6	PHA	polarity bridge A	“0” = current flow from OA1 to OA2
5	MDB	mixed decay enable phase B	“1” = mixed decay
4	CB3	current bridge B.3	MSB
3	CB2	current bridge B.2	
2	CB1	current bridge B.1	
1	CB0	current bridge B.0	LSB
0	PHB	polarity bridge B	“0” = current flow from OB1 to OB2

Serial data word transmitted from TMC236

(MSB transmitted first)

Bit	Name	Function	Remark
11	0	always “0”	
10	0	always “0”	
9	0	always “0”	
8	1	always “1”	
7	OT	overtemperature	“1” = chip off due to overtemperature
6	OTPW	temperature prewarning	“1” = prewarning temperature exceeded
5	UV	driver undervoltage	“1” = undervoltage on VS
4	OCHS	overcurrent high side	3 PWM cycles with overcurrent within 63 PWM cycles
3	OLB	open load bridge B	no PWM switch off for 14 oscillator cycles
2	OLA	open load bridge A	no PWM switch off for 14 oscillator cycles
1	OCA	overcurrent bridge B low side	3 PWM cycles with overcurrent within 63 PWM cycles
0	OCB	overcurrent bridge A low side	3 PWM cycles with overcurrent within 63 PWM cycles

Typical winding current values

Current setting CA3..0 / CB3..0	Percentage of current	Typical trip voltage of the current sense comparator (internal reference or analog input voltage of 2V is used)
0000	0%	0 V (bridge continuously in slow decay condition)
0001	6.7%	23 mV
0010	13.3%	45 mV
...	...	
1110	93.3%	317 mV
1111	100%	340 mV

The current values correspond to a standard 4 Bit DAC, where 100%=15/16. The contents of all registers is cleared to “0” on power-on reset or disable via the ENN pin, bringing the chip to a low power standby mode. All SPI inputs have Schmitt-Trigger function.

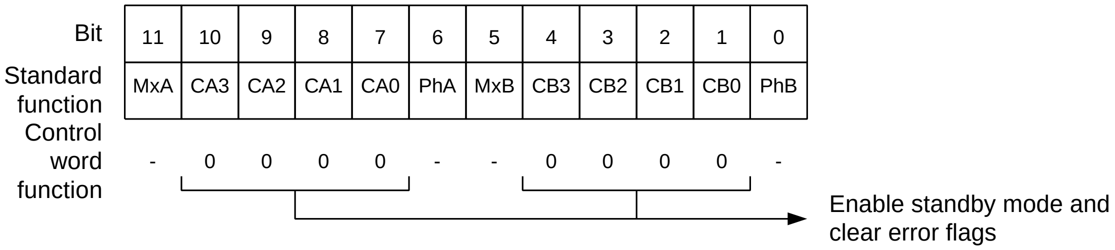
Base current control via INA and INB

In SPI mode, the chip can use an external reference voltage for each DAC. This allows the adaptation to different motors. This mode is enabled by tying pin ANN to GND. A 2.0V input voltage gives full scale current of 100%. In this case, the typical trip voltage of the current sense comparator is determined by the input voltage and the DAC current setting (see table above) as follows:

$V_{TRIP,A} = 0.17\ V_{INA} \times$ “percentage SPI current setting A”
$V_{TRIP,B} = 0.17\ V_{INB} \times$ “percentage SPI current setting B”

A maximum of 3.0V V_{IN} is possible. Multiply the percentage of base current setting and the DAC table to get the overall coil current. It is advised to operate at a high base current setting, to reduce the effects of noise voltages. This feature allows a high resolution setting of the required motor current using an external DAC or PWM-DAC.

Controlling the power down mode via the SPI interface



Bit	11	10	9	8	7	6	5	4	3	2	1	0
Standard function	MxA	CA3	CA2	CA1	CA0	PhA	MxB	CB3	CB2	CB1	CB0	PhB
Control word function	-	0	0	0	0	-	-	0	0	0	0	-

Enable standby mode and clear error flags

Programming current value “0000” for both coils at a time clears the overcurrent flags and switches the TMC236 into a low current standby mode with coils switched off.

Open load detection

Open load is signaled, whenever there are more than 14 oscillator cycles without PWM switch off. Note that open load detection is not possible while coil current is set to “0000”, because the chopper is off in this condition. The open load flag will then always be read as inactive (“0”). During overcurrent and undervoltage conditions, the open load flags also become active!

Overcurrent protection and diagnosis

The TMC236 uses the current sense resistors on the low side to detect an overcurrent: Whenever a voltage above 0.61V is detected, the PWM cycle is terminated at once and all transistors of the bridge are switched off for the rest of the PWM cycle. The error counter is increased by one. If the error counter reaches 3, the bridge remains switched off for 63 PWM cycles and the error flag is read as "active". The user can clear the error condition in advance by clearing the error flag. The error counter is cleared, whenever there are more than 63 PWM cycles without overcurrent. There is one error counter for each of the low side bridges, and one for the high side. The overcurrent detection is inactive during the blank pulse time for the corresponding bridge.

The high side comparator detects a short to GND or an overcurrent, whenever the voltage between VS and VT becomes higher than 0.15 V at any time, except for the blank time period which is logically ORed for both bridges. Here all transistors become switched off for the rest of the PWM cycle, because the bridge with the failure is unknown.

The overcurrent flags can be cleared by disabling and re-enabling the chip either via the ENN pin or by sending a telegram with both current control words set to "0000". In high side overcurrent conditions the user can determine which bridge sees the overcurrent, by selectively switching on only one of the bridges with each polarity (therefore the other bridge should remain programmed to "0000").

Overtemperature protection and diagnosis

The circuit switches off all output power transistors during an overtemperature condition. The overtemperature flag should be monitored to detect this condition. The circuit resumes operation after cool down below the temperature threshold.

Enable pin behavior

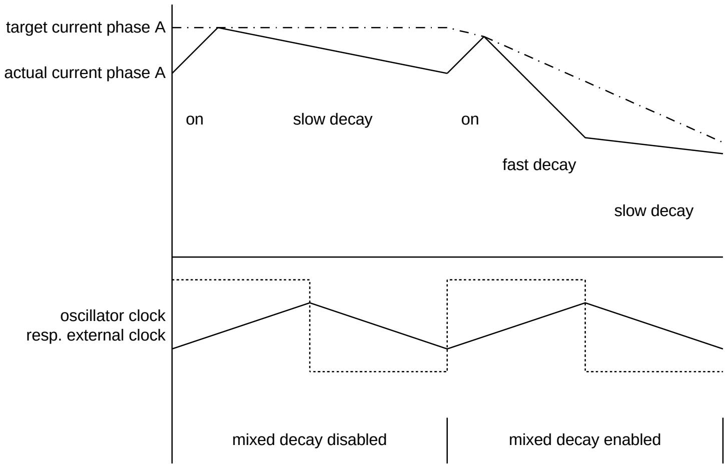
During disable conditions the circuit switches off all output power transistors and goes into a low current shutdown mode. All register contents is cleared to "0", and all status flags are cleared.

Chopper cycle

The TMC236 uses a quiet fixed frequency chopper. Both coils are chopped with a phase shift of 180 degrees. The mixed decay option is realized as a self stabilizing system (pat. fi.), by shortening the fast decay phase, if the ON phase becomes longer. It is advised to enable this for each phase during the second half of each microstepping half-wave, when the current is meant to decrease. This leads to less motor resonance, especially at medium velocities. With low velocities or during standstill mixed decay should be switched off. The mixed decay mode can also be enabled when output current is near to zero, to reduce the minimum motor current which can be achieved.

When polarity is changed on one bridge, the PWM cycle on that bridge becomes restarted at once.

Fast decay switches off both upper transistors, while enabling the lower transistor opposite to the selected polarity. Slow decay always enables both lower side transistors.



Blank time

The TMC236 uses a digital blanking pulse for the current chopper comparators. This prevents current spikes, which can occur during switching action due to capacitive loading, from terminating the chopper cycle. The lowest possible blanking time gives the best results for microstepping: A long blank time leads to a long minimum turn-on time, thus giving an increased lower limit for the current. Please remark, that the blank time should cover both, switch-off time of the lower side transistors and turn-on time of the upper side transistors plus some time for the current to settle. Thus the complete switching duration should never exceed 1.5µs.

The TMC236 allows to adapt the blank time to the load conditions and to the selected slope in four steps:

Blank time settings

BL2	BL1	Typical blank time
GND	GND	0.6 µs
GND	VCC	0.9 µs
VCC	GND	1.2 µs
VCC	VCC	1.5 µs

Standby and shutdown mode

The circuit can be put into a low power standby mode by the user, or, automatically goes to standby on Vcc undervoltage conditions. Before entering standby mode, the TMC236 switches off all power driver outputs. In standby mode the oscillator becomes disabled and the oscillator pin is held at a low state. The standby mode is available via the interface in SPI-mode and via the ENN pin in non-SPI mode.
The shutdown mode can only be entered in SPI-mode using the ENN pin. In shutdown all internal reference voltages also become switched off and the SPI circuit is held in reset.

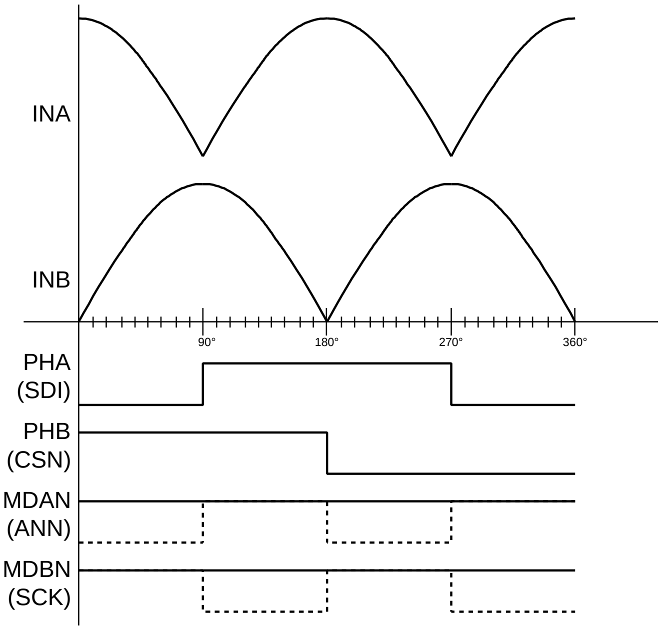
Classical non-SPI control mode (stand alone mode)

The driver can be controlled by analog current control signals and digital phase signals. To enable this mode, tie pin SPE to GND. In this mode, the SPI interface is disabled and the SPI input pins have alternate functions. The internal DACs are forced to “1111”.

Pin functions in stand alone mode

Pin	Stand alone mode name	Function in stand alone mode
SPE		Tie to GND to enable stand alone mode
ANN	MDAN	Enable mixed decay for bridge A (low = enable)
SCK	MDBN	Enable mixed decay for bridge B (low = enable)
SDI	PHA	Polarity bridge A (low = current flow from output OA1 to OA2)
CSN	PHB	Polarity bridge B (low = current flow from output OB1 to OB2)
SDO	ERR	Error output (high = overcurrent on any bridge, or overtemperature). In this mode, the pin is never tristated.
ENN		Standby mode (high active), high causes a low power mode of the device. Setting this pin high also resets all error conditions.
INA, INB		Current control for bridge A, resp. bridge B. Refer to AGND. The sense resistor trip voltage is 0.34V when the input voltage is 2.0V. Maximum input voltage is 3.0V.

Input signals for microstep control in stand alone mode



--- Use dotted line to improve performance at medium velocities

Calculation of the external components

Sense resistor

Choose an appropriate sense resistor (R_S) to set the desired motor current. The maximum motor current is reached, when the coil current setting is programmed to “1111”. This results in a current sense trip voltage of 0.34V when the internal reference or a reference voltage of 2V is used.
When operating your motor in fullstep mode, the maximum motor current is as specified by the manufacturer. When operating in sinestep mode, multiply this value by 1.41 for the maximum current (I_{max}).

$$R_S = V_{TRIP} / I_{max}$$

In a typical application:

$$R_S = 0.34V / I_{max}$$

R_S: Current sense resistor of bridge A, B
V_{TRIP}: Programmed trip voltage of the current sense comparators
I_{max}: Desired maximum coil current

Examples for sense resistor settings

R_S	I_{max}
0.47Ω	723mA
0.33Ω	1030mA
0.22Ω	1545mA

High side overcurrent detection resistor R_{SH}

The TMC236 detects an overcurrent to ground, when the voltage between VS and VT exceeds 150mV. The high side overcurrent detection resistor should be chosen in a way that 100mV voltage drop are not exceeded between VS and VT, when both coils draw the maximum current. In a sinestep application, this is when sine and cosine wave have their highest sum, i.e. at 45 degrees, corresponding to 1.41 times the maximum current setting for one coil. In a fullstep application this is the double coil current.

In a microstep application:

$$R_{SH} = 0.1V / (1.41 \times I_{max})$$

In a fullstep application:

$$R_{SH} = 0.1V / (2 \times I_{max})$$

R_{SH}: High side overcurrent detection resistor
I_{max}: Maximum coil current

However, if the user desires to use higher resistance values, a voltage divider in the range of 10Ω to 100Ω can be used for VT. This might also be desired to limit the peak short to GND current, as described in the following chapter.

Making the circuit short circuit proof

In practical applications, a short circuit does not describe a static condition, but can be of very different nature. It typically involves inductive, resistive and capacitive components. Worst events are unclamped switching events, because huge voltages can build up in inductive components and result in a high energy spark going into the driver, which can destroy the power transistors. The same is true when disconnecting a motor during operation: Never disconnect the motor during operation!

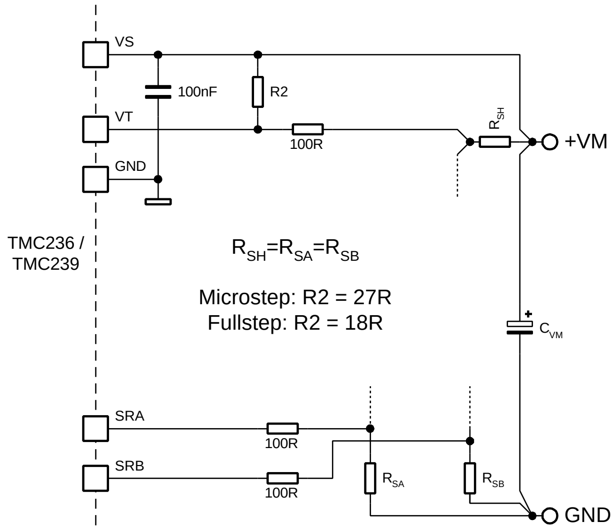
There is no absolute protection against random short circuit conditions, but pre-cautions can be taken to improve robustness of the circuit:
In a short condition, the current can become very high before it is interrupted by the short detection, due to the blanking during switching and internal delays. The high-side transistors allows up to 10A flowing for the selected blank time. The lower the external inductivity, the faster the current climbs. If inductive components are involved in the short, the same current will shoot through the low-side resistor and cause a high negative voltage spike at the sense resistor. Both, the high current and the voltage spikes are a danger for the driver.

Thus there are a two things to be done, if short circuits are expected:

1. Protect SRA/SRB inputs using a series resistance
2. Increase R_{SH} to limit maximum transistor current: Use same value as for sense resistors

The second measure effectively limits short circuit current, because the upper driver transistor with its fixed ON gate voltage of 7V forms a constant current source together with its internal resistance and R_{SH}. A positive side effect is, that only one type of low ohmic resistor is required. The drawback is, that power dissipation increases. A high side short detection resistor of 0.33 Ohms limits maximum high side transistor current to typically 4A. The schematic shows the modifications to be done.

However, the effectiveness of these measures should be tested in the given application.



Oscillator capacitor

The PWM oscillator frequency can be set by an external capacitor. The internal oscillator uses a 28kΩ resistor to charge / discharge the external capacitor to a trip voltage of 2/3 Vcc respectively 1/3 Vcc. It can be overdriven using an external CMOS level square wave signal. Do not set the frequency higher than 100kHz and do not leave the OSC terminal open! The two bridges are choppered with a phase shift of 180 degrees at the positive and at the negative edge of the clock signal.

$$f_{OSC} \approx \frac{1}{40\mu s \times C_{OSC}\,[nF]}$$

f_{OSC}: PWM oscillator frequency
C_{OSC}: Oscillator capacitor in nF

Table of oscillator frequencies

f_{OSC} typ.	C_{OSC}
16.7kHz	1.5nF
20.8kHz	1.2nF
25.0kHz	1.0nF
30.5kHz	820pF
36.8kHz	680pF

Please remark, that an unnecessary high frequency leads to high switching losses in the power transistors and in the motor.

Slope Control Resistor

The output-voltage slope of the full bridge outputs can be controlled to reduce noise on the power supply and on the motor lines and thus electromagnetic emission of the circuit. It is controlled by an external resistor at the SLP pin.

Operational range:

$0k\Omega \leq R_{SLP} \leq 100k\Omega$

The SLP-pin can directly be connected to AGND for the fastest output-voltage slope (respectively maximum output current). In most applications a minimum external resistance of 10 KΩ is recommended to avoid unnecessary high switching spikes.

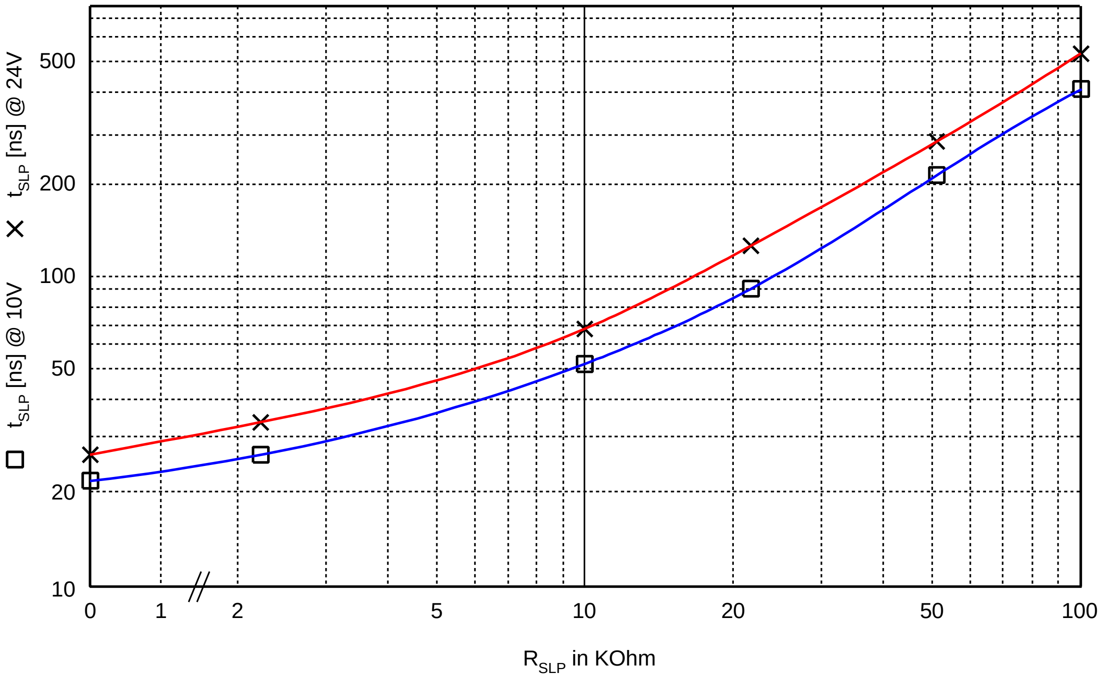
Slope control only affects the upper transistors, and thus the normal direction current, where the circuit feeds energy into the coils. The additional mixed decay slopes, where the coil feeds back current into the power supply, have fixed slope control (corresponding to a 5KΩ to 10KΩ slope control resistor). For applications where electromagnetic emission is very critical, it might be necessary to add additional LC (or capacitor only) filtering on the motor connections.
For these applications emission is lower, if only slow decay operation is used.

Please remark, that there is a trade off between reduced electromagnetic emissions (slow slope) and high efficiency because of low dynamic losses (fast slope).

The following table and graph depict typical behavior measured from 15% of output voltage to 85% of output voltage. However, the actual values measured in an application depend on multiple parameters and may stray in a user application.

Example for slope settings

t_{SLP} typ.	R_{SLP}
30ns	2.2KΩ
60ns	10KΩ
110ns	22KΩ
245ns	51KΩ
460ns	100KΩ



Absolute Maximum Ratings

The maximum ratings may not be exceeded under any circumstances.

Symbol	Parameter	Min	Max	Unit
V_S	Supply voltage		30	V
V_{BR}	Bridge voltage V_{SA}-V_{BRA}, V_{SB}-V_{BRB}		30	V
V_{MD}	Supply and bridge voltage / device disabled max. 20000s		40	V
V_{TRL}	Lower side power transistor voltage V_{OA}-V_{BRA}, V_{OB}-V_{BRB}		30	V
V_{TRH}	Upper side power transistor voltage V_{SA}-V_{OA}, V_{SB}-V_{OB}		30	V
V_{CC}	Logic supply voltage	-0.5	6.0	V
I_{OP}	Output peak current (short pulse)		6	A
I_{OC}	Output current (continuous, one bridge) $T_A \le 70$°C		1500	mA
	$T_A \le 125$°C		800	
V_I	Logic input voltage	-0.3	V_{CC}+0.3V	V
V_{IA}	Analog input voltage	-0.3	V_{CC}+0.3V	V
V_{VT}	Short-to-ground detector input voltage	V_S-1V	V_S+0.3V	V
T_J	Junction temperature	-40	150	°C
T_{STG}	Storage temperature	-55	150	°C

Electrical Characteristics

Operational Range

Symbol	Parameter	Min	Max	Unit
T_{AI}	Ambient temperature industrial (1)	-25	125	°C
T_{AA}	Ambient temperature automotive	-40	125	°C
T_J	Junction temperature	-40	140	°C
V_S	Bridge supply voltage (2)	7	28.5	V
V_{CC}	Logic supply voltage	3.1	5.5	V
f_{CLK}	Chopper clock frequency		50	kHz
R_{SLP}	Slope control resistor	0	110	KΩ

(1) The circuit can be operated up to 140°C, but output power derates.
(2) The maximum operating supply voltage is reduced from 30V to 28.5V with inductive loads, because inductive loads increase the output voltage above / below the supply voltage rail in fast decay and change of polarity situations.

DC Characteristics

DC characteristics contain the spread of values guaranteed within the specified supply voltage and temperature range unless otherwise specified. Typical characteristics represent the average value of all parts.
Logic supply voltage: V_{CC} = 3.0 V ... 5.5 V, Junction temperature: T_J = -40°C … 150°C,
Bridge supply voltage : V_S = 7 V … 28.5 V
(unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$R_{OUT,Sink}$	R_{DSON} of sink-transistor	T_A = 25°C $V_S \geq$ 8V		0.10	0.12	Ω
$R_{OUT,Source}$	R_{DSON} of source-transistor	T_A = 25°C $V_S \geq$ 8V		0.20	0.24	Ω
$R_{OUT,Sink}$	R_{DSON} of sink-transistor max.	T_J =150°C $V_S \geq$ 8V		0.17	0.20	Ω
$R_{OUT,Source}$	R_{DSON} of source-transistor max.	T_J =150°C $V_S \geq$ 8V		0.34	0.41	Ω
V_{DIO}	Diode forward voltages of O_{xx} MOSFET diodes	T_J = 25°C I_{OXX} = 1.05A		0.82	1.10	V
V_{CCUV}	VCC undervoltage		2.5	2.7	2.9	V
V_{CCOK}	VCC voltage o.k.		2.7	2.9	3.1	V
I_{CC}	VCC supply current	f_{osc} = 25 kHz	0.5	0.8	1.0	mA
I_{CCSTB}	VCC supply current standby			390	605	µA
I_{CCSD}	VCC supply current shutdown	ENN = 1		<1	20	µA
V_{SUV}	VS undervoltage		5.5	5.9	6.2	V
V_{CCOK}	VS voltage o.k.		6.1	6.4	6.7	V
I_{SSD}	VS supply current shutdown or standby	V_S = 14V		28		µA
V_{IH}	High input voltage (all digital inputs)		2.2		VCC + 0.3 V	V
V_{IL}	Low input voltage (all digital inputs)		-0.3		0.7	V
V_{IHYS}	Input voltage hysteresis (all digital inputs)		100	250	500	mV
V_{OH}	High output voltage (output SDO)	$-I_{OH}$ = 1mA	VCC – 0.6	VCC – 0.2	VCC	V
V_{OL}	Low output voltage (output SDO)	I_{OL} = 1mA	0	0.2	0.4	V
$-I_{ISL}$	Low input current (all digital inputs)	V_I = 0	2		70	µA
		V_{CC} = 3.3V		10		µA
		V_{CC} = 5.0V		25		µA
$-I_{IEL}$	Low input current (input ENN)	V_I = 0	10		50	µA
		V_{CC} = 3.3V		20		µA
		V_{CC} = 5.0V		30		µA
V_{OSCH}	High input voltage threshold (input OSC)		tbd	2/3 VCC	tbd	V
V_{OSCL}	Low input voltage threshold		tbd	1/3 VCC	tbd	V

	(input OSC)					
V_{VTD}	VT threshold voltage (referenced to VS)		-130	-150	-170	mV
V_{SRT}	SRA / SRB 100% setting threshold using internal reference or 2V at INA / INB		320	340	360	mV
V_{SRS}	SRA / SRB overcurrent detection threshold		580	610	640	mV
V_{SROFFS}	SRA / SRB comparator offset voltage		-6	0	6	mV
R_{INAB}	INA / INB input resistance	Vin ≤ 3 V	200	264	300	kΩ

AC Characteristics

AC characteristics contain the spread of values guaranteed within the specified supply voltage and temperature range unless otherwise specified. Typical characteristics represent the average value of all parts.

Logic supply voltage: $V_{CC} = 5.0V$, Bridge supply voltage: $V_S = 14.0V$,
Ambient temperature: $T_A = 27°C$

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{OSC}	Oscillator frequency using internal oscillator	$C_{OSC} = 1nF$	22	25	28	kHz
t_{RS}, t_{FS}	Rise and fall time of outputs Oxx with $R_{SLP}=0$	V_o 15% to 85% $I_{OXX} = 800mA$		25		ns
t_{RS}, t_{FS}	Rise and fall time of outputs Oxx with $R_{SLP} = 25K\Omega$	V_o 15% to 85% $I_{OXX} = 800mA$		125		ns
t_{RS}, t_{FS}	Rise and fall time of outputs Oxx with $R_{SLP} = 50K\Omega$	V_o 15% to 85% $I_{OXX} = 800mA$		250		ns
T_{BL}	Blank time	BL1, BL2 = V_{CC}	1.35	1.5	1.65	µs
T_{ONMIN}	Minimum PWM on-time	BL1, BL2 = GND		0.7		µs

Thermal Protection

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
T_{JOT}	Thermal shutdown		140	145	150	°C
T_{JOTHYS}	Thermal hysteresis			10		°C
T_{JWT}	Prewarning temperature		130	135	140	°C

Thermal Characteristics

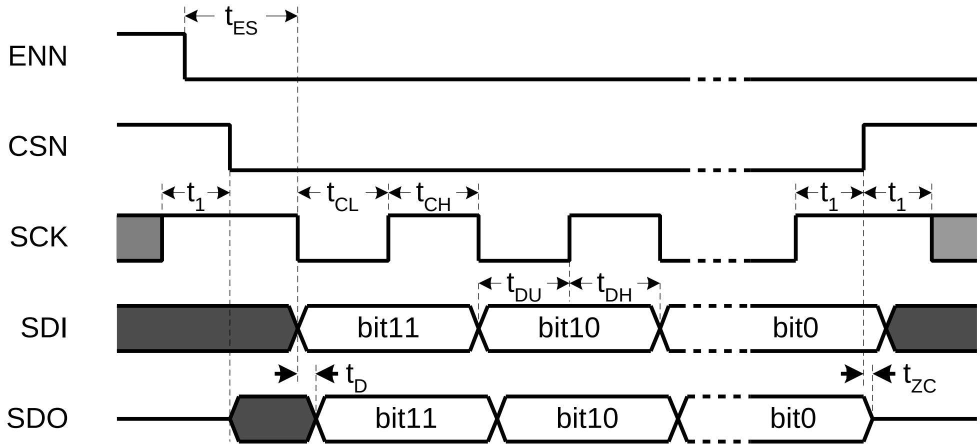
Symbol	Parameter	Conditions	Typ	Unit
R_{THA12}	Thermal resistance bridge transistor junction to ambient, one bridge chopping, fixed polarity	soldered to 2 layer PCB	88	°K/W
R_{THA22}	Thermal resistance bridge transistor junction to ambient, two bridges chopping, fixed polarity	soldered to 2 layer PCB	68	°K/W
R_{THA14}	Thermal resistance bridge transistor junction to ambient, one bridge chopping, fixed polarity	soldered to 4 layer PCB (pessimistic)	84	°K/W
R_{THA24}	Thermal resistance bridge transistor junction to ambient, two bridges chopping, fixed polarity	soldered to 4 layer PCB (pessimistic)	51	°K/W

Typical Power dissipation at high load / high temperature

Coil:	L_W = 10mH, R_W = 5.0Ω
Chopping with:	t_{DUTY} = 25% ON, only slow decay

Current both bridges on	**Current one bridge on**	**Ambient temperature T_A**	**Motor supply voltage V_M**	**Slope t_{SLP}**	**Chopper frequency f_{CHOP}**	**Typ total power dissipation P_D**
560 mA	-	105 °C	16 V	400 ns	25 KHz	700 mW
-	800 mA	105 °C	16 V	400 ns	25 KHz	550 mW
560 mA		125 °C	14 V	min.	20 KHz	400 mW
	800 mA	125 °C	14 V	min.	20 KHz	400 mW
1000 mA	-	70 °C	28 V	min.	25 KHz	1400 mW
-	1500 mA	70 °C	28 V	min.	25 KHz	1200 mW

Interface Timing



Propagation times

(3.0 V ≤ VCC ≤ 5.5 V, -40°C ≤ Tj ≤ 150°C; V_{IH} = 2.8V, V_{IL} = 0.5V; tr, tf = 10ns; C_L = 50pF, unless otherwise specified)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
f_{SCK}	SCK frequency	ENN = 0	DC		4	MHz
t_1	SCK stable before and after CSN change		50			ns
t_{CH}	Width of SCK high pulse		100			ns
t_{CL}	Width of SCK low pulse		100			ns
t_{DSU}	SDI setup time		40			ns
t_{DH}	SDI hold time		50			ns
t_D	SDO delay time	C_L = 50pF		37	80	ns
t_{ZC}	CSN high to SDO high impedance			50		ns
t_{ES}	ENN to SCK setup time		tbd			µs
t_{PD}	CSN high to output Hxx/Lxx delay			tbd		µs

ESD protection

Please be aware, that the TMC236 is an ESD sensitive device due to integrated high performance MOS transistors.

ESD sensitive device

If the ICs are manually handled before / during soldering, special precautions have to be taken to avoid ESD voltages above 100V HBM (Human body model). For automated SMD equipment the internal device protection is specified with 1000V CDM (charged device model), tbf.

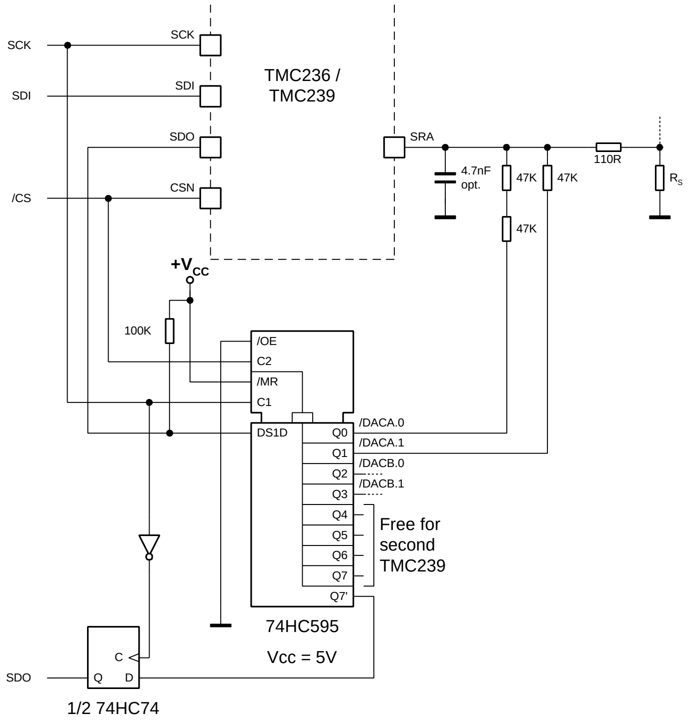
When soldered to the application board, all inputs and outputs withstand at least 1000V HBM.

Application note: Extending the microstep resolution

For some applications it might be desired to have a higher microstep resolution, while keeping the advantages of control via the serial interface. The following schematic shows a solution, which adds two LSBs by selectively pulling up the SRA / SRB pin by a small voltage difference. It assumes a full scale sense voltage of 340mV. The circuit still takes advantage of completely switching off of the coils when the internal DAC bits are set to “0000”. This results in the following comparator trip voltages:

Current setting (MSB first)	**Trip voltage**
0000xx	0 V
000111	5.8 mV
000110	11.5 mV
000101	17.3 mV
000100	23 mV
...	
111101	334.2 mV
111100	340 mV

SPI bit	15	14	13	12	11	10	9	8
DAC bit	/B1	/B0	/A1	/A0	MDA	A5	A4	A3
SPI bit	7	6	5	4	3	2	1	0
DAC bit	A2	PHA	MDB	B5	B4	B3	B2	PHB



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[i] SPI is a trademark of Motorola