



# TMC262–EVAL manual

Evaluation board for the TMC262 stepper motor driver IC with coolStep

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## 1 Features

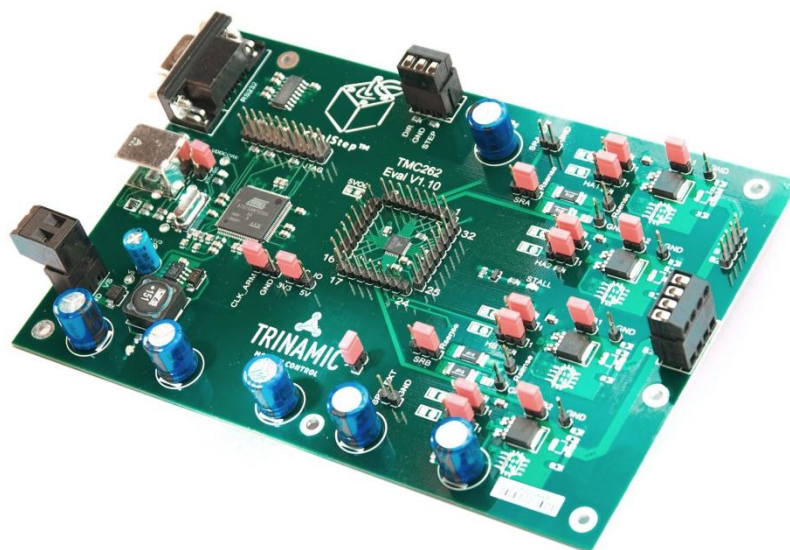
The TMC262 evaluation board features a TMC262 with external power MOSFETs plus a microcontroller, which allows interfacing to a PC for visualization and control of all parameters. The motor can be operated via the step and direction interface both, using an external source, and using the integrated microcontroller as a step generator.

### Highlights

- Evaluate all features of the TMC262
- Use stallGuard2™ with your motor
- Use coolStep™ with your motor
- Control all parameters from a PC using special software or TMCL-PC
- Motor current can be set to up to 1A, 2A or up to 4A (soldering jumper) via on-board sense resistors
- Supply voltage up to 40V (MOSFETs can be exchanged against 60V 2A types)
- Access all pins of the TMC262

### Motor type

- 2 phase Stepper



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### 3 General Description

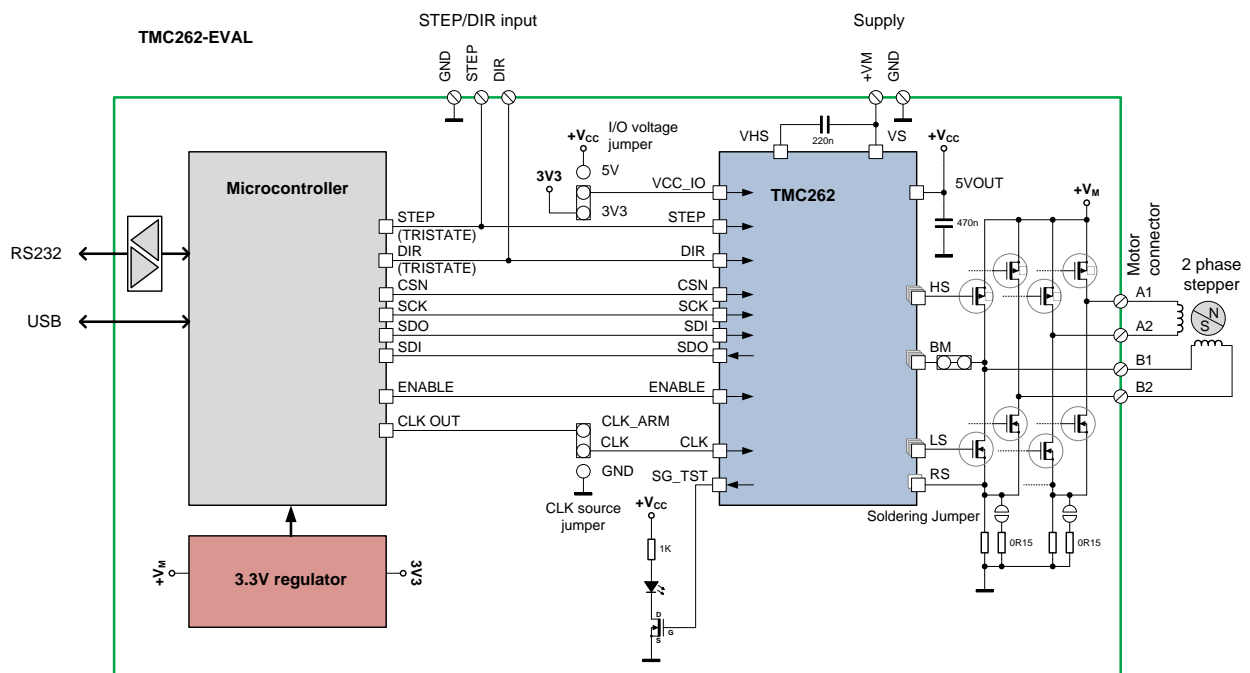


figure 1: application block diagram as realized on TMC262-EVAL

The TMC262-EVAL board features the TMC262 plus a microcontroller, which realizes an interface to a PC.

#### 3.1 Power driver stage

The power MOSFETs on resistance mainly influences the current and voltage capability of the board. Therefore, a choice of different MOSFETs can be soldered to the board.

##### Component selection:

- The TMC262 driver has powerful 40V MOSFETs FDD8424H for motor currents up to 6A peak. With these MOSFETs, the supply voltage is limited to 40V.
- The MOSFETs can be exchanged against complementary N&P channel SO8 types, e.g. 60V type SI4559ADY (SO8). These will allow a motor current of max. 3A peak.
- Small 60V MOSFETs SI3458BDV and SI3459BDV are also possible for up to 2A peak.

### 3.2 Sense resistors and current setting

There are two pairs of sense resistors on the board (R18 and R40, R23 and R41). As a default, a 150mΩ 2510 type resistor is used (330mΩ on earlier versions of the board). A second resistor can be switched in parallel to double the motor current. For different current ranges, the sense resistors can be exchanged (see table). The sense resistors should be chosen in a way, that they fit the maximum required motor current. The current can be scaled down in the TMC262. There also is a half current setting available (VSENSE=1), which halves the sense resistor power dissipation. At current settings above 4A, care has to be taken with the MOSFET power stage temperature, as the MOSFET power dissipation gets higher. On the evaluation board, the distance between MOSFETs and TMC262 is quite large, so the TMC262 does not directly see MOSFET heating and will not be able to protect the MOSFETs against overtemperature.

Motor current limit at full current setting via Step/Direction interface (example values):

Sense resistor value $R_{SENSE}$	Current (peak) $I_{COIL}$	Current RMS $I_{COILRMS}$	Current (peak) $I_{COIL}$	Current RMS $I_{COILRMS}$
	VSENSE=0		VSENSE=1	
330mΩ	0.9	0.6	0.5	0.34
330mΩ    330mΩ	1.8	1.25	1.0	0.68
270mΩ	1.2	0.8	0.6	0.42
270mΩ    270mΩ	2.2	1.5	1.2	0.84
220mΩ	1.4	0.9	0.7	0.51
220mΩ    220mΩ	2.7	1.9	1.5	1.0
150mΩ	2.0	1.4	1.1	0.8
150mΩ    150mΩ	4.0	2.8	2.1	1.5
100mΩ	3.0	2.1	1.5	1.1
100mΩ    100mΩ	5.9	4.2	2.9	2.3
50mΩ    50mΩ	-	-	6.4	4.5

In a practical application, especially with low ohmic sense resistors, trace resistance can significantly influence the reachable current. Care has to be taken to realize a compact layout with low GND resistance in order to reach a good microstep performance.

#### Component selection:

It is important to use low inductivity resistors like Vishay WSL2512.

### 3.3 Power supply filter capacitors

As a chopper operated motor driver draws current in short intervals, it causes noise on the power supply. Therefore it is important to filter the power supply using a capacitor, in order to reduce electromagnetic emission (EME) via power supply cables. Further, the capacitor should be able to store energy fed back from the motor, when the motor becomes decelerated. This depends on the application velocity and mechanics.

#### Component selection:

Due to the high frequent ripple, low ESR capacitors are required for this application. The evaluation board uses Vishay 150RMI series capacitors. These provide a very long life time even at high environment temperatures. The required total capacity depends on desired motor current and on the distance to the power supply.

### 3.4 Optional components

There are optional filter components designed in on the board. These allow experimenting with EME filters, e.g. RC and LC filter with RC dampening. Please see the board schematic for sample values.

## 4 Board Pinning

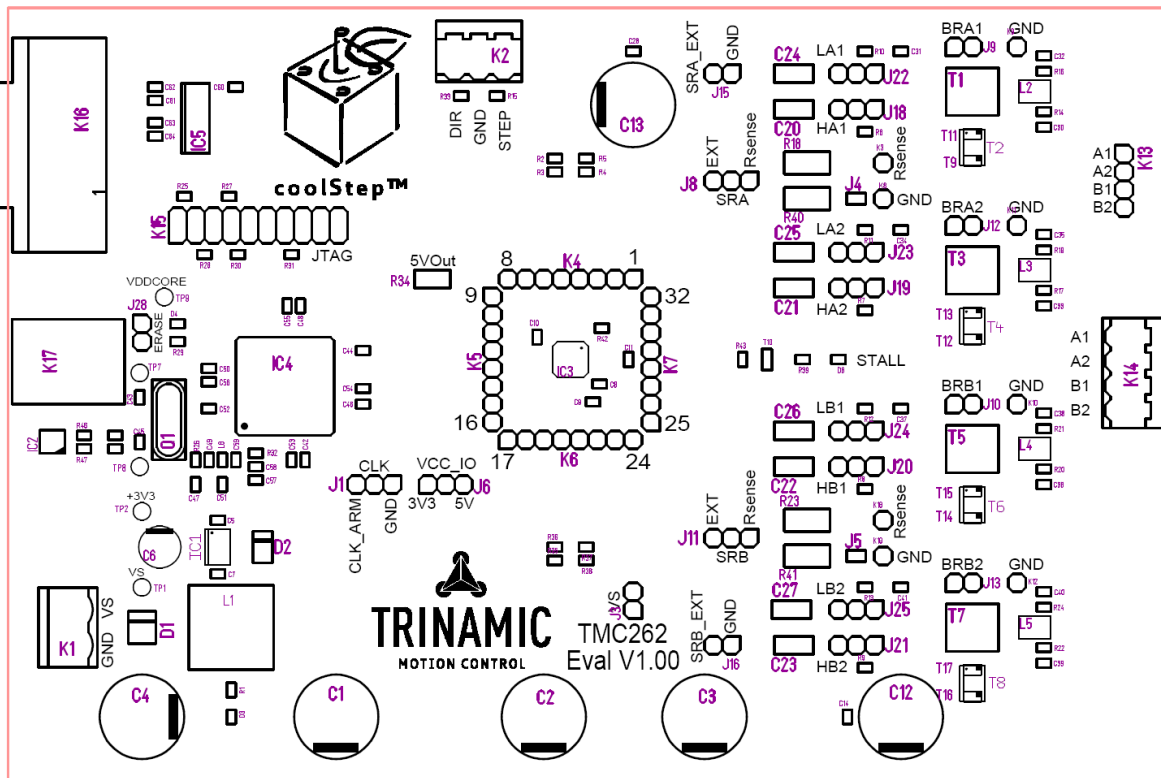


figure 2: component placement on the board

### 4.1 Connectors

#### 4.1.1 Power supply connector K1

Pin	Number	Level	Description
GND	1	GND	Digital and analog low power GND
VS	2	9V-40V	Supply voltage. Provide sufficient current capability for driving the motor.

#### 4.1.2 Stepper motor connector K14 (or K13)

Pin	Number	Level	Description
A1	1	VS	Motor coil A connection 1
A2	2	VS	Motor coil A connection 2
B1	3	VS	Motor coil B connection 1
B2	4	VS	Motor coil B connection 2

*Attention: Do not pull or plug the motor connector during operation, as inductive spikes could destroy the driver. First disable the driver (there is a button in the Eval software) or switch off the power supply.*

### 4.1.3 Step and direction input K2

Pin	Number	Level	Description
DIR	1	VIO	Direction input of TMC262. Direction output of microcontroller when enabled via software (step/dir → RUN)
GND	2	GND	Ground reference
STEP	3	VIO	Direction input of TMC262. Step output of microcontroller when enabled via software (step/dir → RUN)

### 4.1.4 JTAG programmer K15

Pin	Number	Level	Description
NRST	15	3.3V	CPU reset pin. Place a jumper between pin 15 and 16 to disable the CPU. In this mode, the CPU does not drive the TMC262, and you can freely access its SPI interface via the header connectors next to the TMC262.
GND	16	GND	Ground

This connector can be used for debugging of CPU software and for programming via JTAG.

### 4.1.5 USB (K17) and RS232 (K16)

PC interface for operation with the demonstration software. The USB port is handled as a virtual COM port.

## 4.2 Jumpers

### 4.2.1 Clock selection J1

Setting	Function	Description
1-2	GND	TMC262 uses internal clock
2-3	CLK_ARM	TMC262 uses clock signal provided by the microcontroller.

### 4.2.2 VCC\_IO J6

Selects the VCC\_IO voltage source for the TMC262.

Setting	Function	Description
1-2	3V3	3.3V supply of microcontroller
2-3	5V	5V voltage supplied by TMC262 voltage regulator

### 4.2.3 VSENSE J8, J11 (J15, J16)

J8 and J11 select the source of the sense resistor voltage of the TMC262. Always use position 1-2 for normal operation.

Setting	Function	Description
1-2	sense resistor	Normal operation, the TMC262 uses the shunt resistors for current sensing
2-3	external input	Sense resistor signals can be supplied via J15 or J16 for testing purpose

#### 4.2.4 Gate jumpers LA1, HA1, J22, J18, etc

Connects the TMC262 gate driver outputs to the MOSFETs

Setting	Function	Description
1-2	normal operation	MOSFET gate controlled by TMC262
2-3	external load	Gate driver signal available at test load output (C24, C20, etc.)

#### 4.2.5 Bridge center sense jumpers BRA1, BRA2, BRB1, BRB2, J9, 12, J10, J13

Connects the bridge outputs to TMC262 BM pins

Setting	Function	Description
1-2	normal	TMC262 sees the bridge center points
open	BM open	This setting allows testing of the short to GND condition without shorting the bridge output.

#### 4.2.6 Erase Jumper J28

Erases the CPU

Setting	Function	Description
1-2	Erase	<i>Attention:</i> Erases the processor. Reprogram it via RS232 using the SAMBA tool.
open	operation	

## 5 Electrical Characteristics

### 5.1 Operational Range

Parameter	Symbol	Min	Max	Unit
Ambient temperature	$T_A$	-25	85	°C
Supply voltage (with the original 40V MOSFETs soldered on the board)	$V_{VS}$	9	40	V
Supply voltage (with 60V MOSFETs SI4559ADY)	$V_{VS}$	9	60	V
Step and Direction input voltage high level ( <i>Attention:</i> The maximum high level depends on the VIO jumper setting)	$V_{VIO}$	2.40	VIO+0.7	V



## 6 Getting started

Connect a stepper motor to the board, connect the PC via RS232 or USB and use a laboratory power supply to power the board with for example 24V.

Now, copy the software to your PC and install USB driver, if necessary.

### 6.1 First steps

Start the evaluation kit software.

#### 6.1.1 Connecting to the board

Select the appropriate port and select Interface / Open. For USB connection, the board uses a virtual COM port. You need to select the .inf file from the installation directory to set it up.

#### 6.1.2 Current setting

As a first step, you should set the appropriate current setting for your motor: Go to the tab SGCSCONF and select the correct value for the sense resistor, to see the actual current setting. The current scale can be selected from 7 (default) to 31. You get the best motor performance with a high value between 16 and 31. If your calculation shows, that you need a value below 16, please go to the tab DRVCONF and select VREF=1/36 instead of 1/18. If you cannot reach the desired motor current, please change the sense resistor to a lower value. Please refer chapter 3.2 for sense resistor selection.

Please be careful to not select a too high current value, as a too high current setting could destroy the motor by overheating.

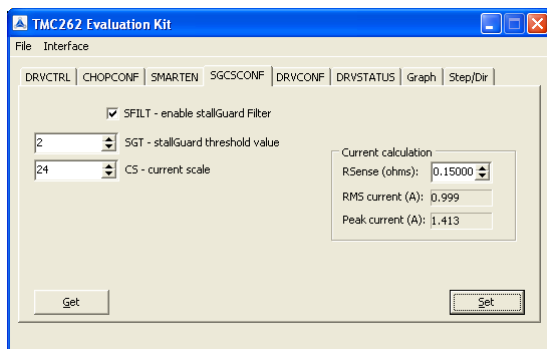


figure 3: Evaluation software: Current setting

Now, please check the DRVSTATUS tab. The indicators should give a reading and show stable values.

#### 6.1.3 Starting the motor

To move the motor using the internal step and direction source, select acceleration and velocity (signed) setting and press the Run button. Press the get button in any of the tabs, to read out actual settings. In case you want faster motion, stop the motor, go to the tab DRVCTRL and reduce microstep resolution. Best performance is achieved in 256 times microstepping, or in 16 times microstepping with step interpolation active (please check INTPOL).

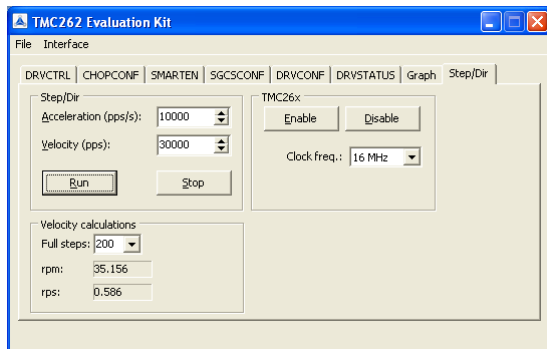


figure 4: Evaluation software: Starting the motor

#### 6.1.4 Clock frequency setting

You can modify the TMC262 clock frequency delivered from the CPU to the TMC262. As also the SPI and Step signal input synchronization are affected by this setting, we advise working with 16MHz or with the internal clock frequency (Jumper setting for internal or external CLK should be done before board power up). Default is 16MHz.

#### 6.1.5 Using stallGuard2™ and coolStep™

In order to use the stallGuard2™ functionality and coolStep™, you should first tune the stallGuard2™ sensitivity. As a first step, you should enable the stallGuard™ filter bit SFILT in the tab SGCSCONF.

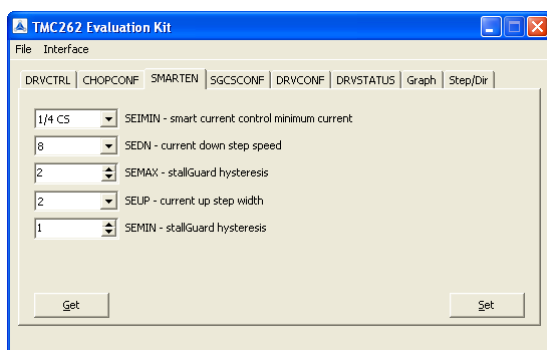


figure 5: Evaluation software: coolStep setting

Therefore, operate the motor at a reasonable velocity (taking into account your application) and look at the stallGuard™ value (SG) in the DRVSTATUS tab or watch the stallGuard value in the Graph tab. Now, apply slowly increasing mechanical load to the motor. If the motor stalls before the stallGuard™ value reaches zero, go to the SGCSCONF tab and decrease the stallGuard threshold value (SGT). A good starting value is zero. You can apply negative values and positive values. If the values leave a range outside +/-10, probably your velocity setting is too high or too low. If the SG value reaches zero far before the motor stalls, increase the SGT value.

The optimum setting is reached, when the stallGuard2™ value reaches zero at increasing load shortly before the motor stalls due to overload.

Now, you are ready to enable coolStep™! Go to the SMARTEN tab and set SEMAX and SEMIN to a value different from 0. This enables coolStep. A good value for both is 1 or 2 for most motors. Now, coolStep is enabled and you should see the current scale SE decreasing when the motor does not see any load (see tab Graph). You can modify current increase and current reduction speed by changing SEUP and SEDN. You can select, if the current becomes scaled down to ½ of CS or to ¼ of CS, using SEIMIN setting.

For details and sample traces, please see the TMC262 data sheet.

**Hint:**

For first tests, we recommend setting SEIMIN to  $\frac{1}{2}$ , as the  $\frac{1}{4}$  setting might not work stable with increasing load without adapting the SGT value to the actual motor current.

**6.1.6 Optimizing the chopper settings**

In principle, you can run the motor with default settings, but you might want to try improving or modifying the chopper setting for smoothest performance of the motor and for low chopper noise. You can try both chopper modes over your full velocity range and decide afterwards, which one fits best. In order to tune the chopper settings, you can follow the following instructions which are based on your evaluation of motor behavior:

1. Start the motor at the desired velocity: For tuning of const  $t_{OFF}$  mode fast decay time, a medium velocity is preferred, e.g. 1-2 rotations per second. In order to tune chopper hysteresis setting for standard chopper mode (spreadCycle), or sine wave offset in const  $t_{OFF}$  mode, a low velocity should be preferred, e.g. 0.1-1 rotations per second.
2. Go to the tab CHOPCONF to choose the chopper mode and its settings. Now, you can select standard chopper (spreadCycle) or classical const  $t_{OFF}$  chopper.
3. For both modes, the off time  $t_{OFF}$  is a major component. A setting between 2 and 7 fits most motors for spread cycle, choose 4 to 15 for const  $t_{OFF}$  chopper. A lower setting increases the chopper frequency.
4. Now, you can tune the zero crossing behavior:  
 In the standard chopper mode, you can check behavior for different HSTART settings to improve motor behavior: Start with a low HSTART setting and increase HSTART, until the motor turns smoothest. If you reach maximum HSTART value, you might need to increase HEND also. Further increasing the value will not bring further benefit.  
 In constant  $t_{OFF}$  mode, a positive sine wave offset improves zero transition performance and fast decay time influences motor resonance. You might try pure slow decay operation if fastest motor velocity is desired. First, optimize fast decay time, starting from a low value, until the motor turns smoothest. Further increasing fast decay time might be necessary for higher velocity settings. As a second step, increase the sine wave offset starting from 0, until smoothest motor operation is yielded. There will be an optimum setting at a certain value. A higher setting causes a jump in the coil current sine wave zero crossing, a lower value causes a flattening.
5. There is no need to modify the blank time, unless you change the MOSFETs on the board.

**6.2 Writing the settings to a .C file**

You can load and store all settings made in the evaluation board. They are stored in a .262 text file, which is user readable.

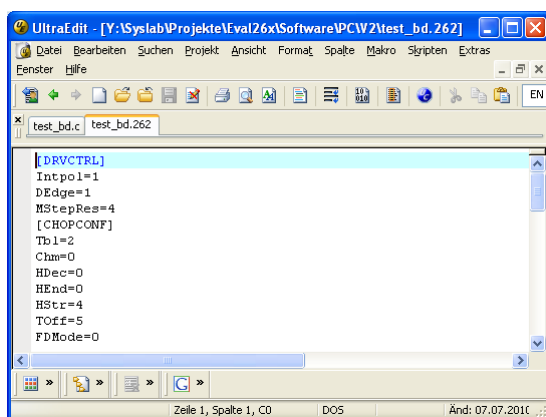
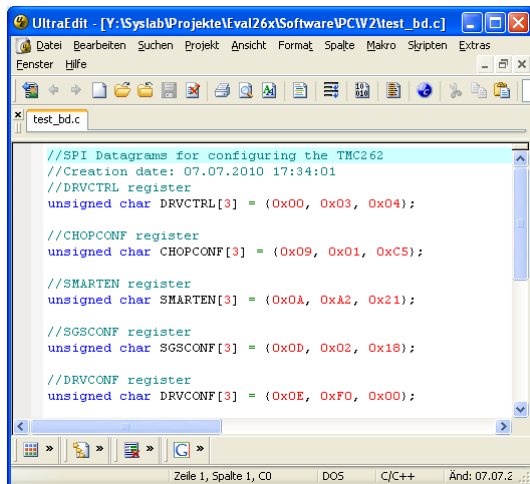


figure 6: .262 file opened in text editor

In order to transfer the settings into your own software, there is a C language export function. This will write out the initialization values for the TMC262 in a C syntax form, which allows easy sending via a microcontroller SPI interface.



```

//SPI Datagrams for configuring the TMC262
//Creation date: 07.07.2010 17:34:01
//DRVCTRL register
unsigned char DRVCTRL[3] = {0x00, 0x03, 0x04};

//CHOPCONF register
unsigned char CHOPCONF[3] = {0x09, 0x01, 0xC5};

//SMARTEN register
unsigned char SMARTEN[3] = {0x0A, 0xA2, 0x21};

//SGSCONF register
unsigned char SGSCONF[3] = {0x0D, 0x02, 0x18};

//DRVCONF register
unsigned char DRVCONF[3] = {0x0E, 0xF0, 0x00};

```

figure 7: .c file opened in text editor

## 7 TMCL commands

The board does not support stand-alone TMCL operation, but its PC interface uses a subset of TMCL commands for parameterization. You can use the direct mode of the TMCL-IDE to explore it, or remote control the module with TMCL-PC in order to drive sequences.

The address of the TMC262-EVAL is always fixed 1.

The board supports a number of SAP and GAP commands in order to set parameters.

Movements can be started using MVP and ROL/ROR commands. The unit of Position is in microsteps, velocity in steps/second and acceleration in steps/s<sup>2</sup>.

0: target position (normally set via MVP)

1: actual position

2: target velocity (normally set via ROL/ROR/MST commands)

3: actual velocity

4: maximum velocity with positioning

5: acceleration

181: stop On Stall Velocity

6: current (Register SGSCONF Bits CS4..CS0)

140: micro step resolution (Register DRVCTRL, Bits MRES3..MRES0, but reversed (8-x), for TMCL-compatibility)

160: DRVCTRL.INTPOL

161: DRVCTRL.DEDGE

162: CHOPCONF.[TBL1..TBL0]

163: CHOPCONF.CHM

184: RNDTF

164: CHOPCONF.[HDEC1..HDEC0]

165: CHOPCONF.[HEND3..HEND0]

166: CHOPCONF.[HSTR2..HSTR0]

167: CHOPCONF.[TOFF3..TOFF0]

168: SMARTEN.SEIMIN

169: SMARTEN.[SEDN1..SEDN0]

170: SMARTEN.[SEMAX3..SEMAX0]

171: SMARTEN.[SEUP1..SEUP0]

172: SMARTEN.[SEMIN3..SEMIN0]

173: SGSCONF.SFILT

174: SGSCONF.[SGT6..SGT0]

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185: DRVCONF.TST  
175: DRVCONF.[SLPH1..SLPH0]  
176: DRVCONF.[SLPL1..SLPL0]  
177: DRVCONF.DISS2G  
178: DRVCONF.[TS2G1..TS2G0]  
183: DRVCONF.SDOFF  
179: DRVCONF.VSENSE

further parameters, which can be read, only (only used with GAP):

180: actual current setting (Bits RD9..RD0 of TMC262 read back data, with RDSEL=10)

182: actual microstep position (Bits RD9..RD0 of read back data, with RDSEL=00)

206: actual load value (Bits RD9..RD0 of read back data, with RDSEL=01)

207: state of SGTEST-Pins

208: error bits of read back data

8: 1=target position reached, 0=target position not reached.

Parameters 0,1,2,3,4,5,8 and 181 are not directly coupled to TMC262 but are connected to the software ramp generator in the microcontroller.

## 8 Revision History

### 8.1 Documentation Revision

Version	Author BD=Bernhard Dwersteg	Description
0.10	BD	Initial version of documentation
0.12	BD	Added notes on first hand labeled TMC262 prototypes
0.13	BD	Comments on power supply components
0.14	BD	New sense resistor value 150mΩ, new photo, more details in getting started
0.15	BD	New software with export function, some hints
0.16	BD	Adapted sense resistor dependent current table to new V2 ICs.
1.0	BD	minor changes
1.1	BD	added TMCL command information, new description for parameter optimization

Table 1: Documentation Revisions