TMC603EVAL – MANUAL

Evaluation board for the TMC603 three phase motor driver with BLDC back EMF commutation hallFX™

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1 Features

The TMC603 evaluation board makes it possible to evaluate the features of the TMC603 three phase BLDC motor driver with back EMF commutation hallFX™. On the evaluation board the Infineon XC886 microcontroller is used to control the TMC603. The microcontroller's FLASH memory contains a program which configures the TMC603 and controls the communication with the PC via the CAN interface or the RS232 interface. To use the CAN interface the TRINAMIC USB-2-X is available as an USB adapter. Windows based PC software allows tuning of all operation parameters for every three phase BLDC motor.

Motor type

- 3 phase BLDC motor
- block commutation
- Rotor position feedback: sensorless or hall sensor

Highlights

- Up to 6A (I_{RMS}) nominal motor current
- 12V to 48V operating voltage
- Integrated current measurement using power MOS transistor RDSon
- hallFX™ sensorless back EMF commutation emulates hall sensors
- Integrated Break-before-Make logic: No special microcontroller PWM hardware required
- EMV optimized current controlled gate drivers – up to 150mA possible
- Overcurrent / Short to GND and undervoltage protection and diagnostics integrated
- Internal QGD protection: Supports latest generation of Power MOSFETs
- Integrated supply concept: Step down switching regulator
- Common rail charge pump allows for 100% PWM duty cycle
- Communication to the PC via CAN interface and RS232 interface
- Firmware update via RS232 interface

Please check our website for the latest version of manual and firmware!
www.trinamic.com

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Life support systems are equipment intended to support or sustain life, and whose failure to perform, when properly used in accordance with instructions provided, can be reasonably expected to result in personal injury or death.

2 Contents

3 General Description

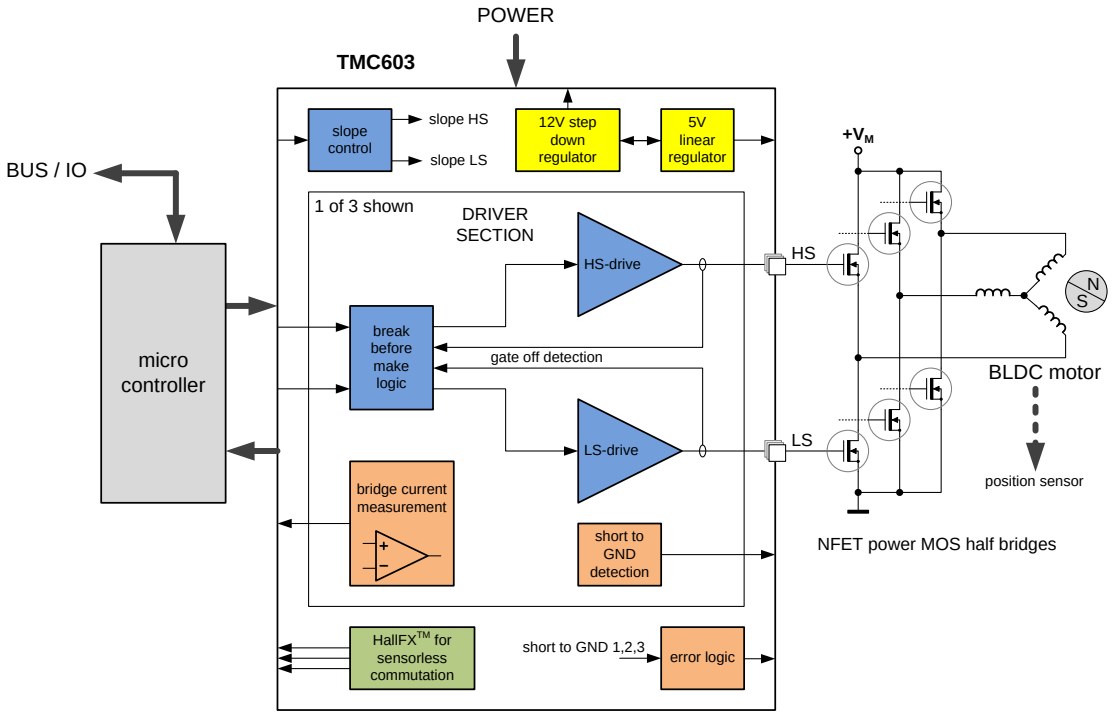

Figure 1: The structure of the TMC603 evaluation board

The TMC603 is a BLDC driver IC using external power MOS transistors. Its unique feature set allows equipping inexpensive and small drive systems with a maximum of intelligence, protection and diagnostic features. Depending on the desired commutation scheme and the bus interface requirements, the TMC603 forms a complete motor driver system in combination with an external 8 bit processor (Infineon XC886). The complete analog amplification and filtering frontend as well as the power driver controller are realized in the TMC603.

4 Quick Start

4.1 Connecting the motor

For a first quick start, plug the jumpers on the evaluation board like shown in Figure 2. Please check if the jumpers X212, X213 and X214 are plugged. Connect a three phase BLDC motor to the connector X301 (motor coil output). The pins are marked by “U”, “V” and “W”. Please note that the BLDC motors may only be connected to or disconnected from the evaluation board while the board is disconnected from power supply, as otherwise the evaluation board could get damaged!

Figure 2: Default settings of jumpers for quick start

4.2 Connecting the RS232 interface and power supply

Connect the RS232 interface (X116) to the PC by using a null modem cable. The baud rate is automatically set to 115200 baud by the PC software. Now, connect the power supply between 12V and 48V and at least 1A to the connector X201 (power supply). The positive terminal is marked “12V-48V”. The green “POWER ON” LED will light up after attaching the power supply.

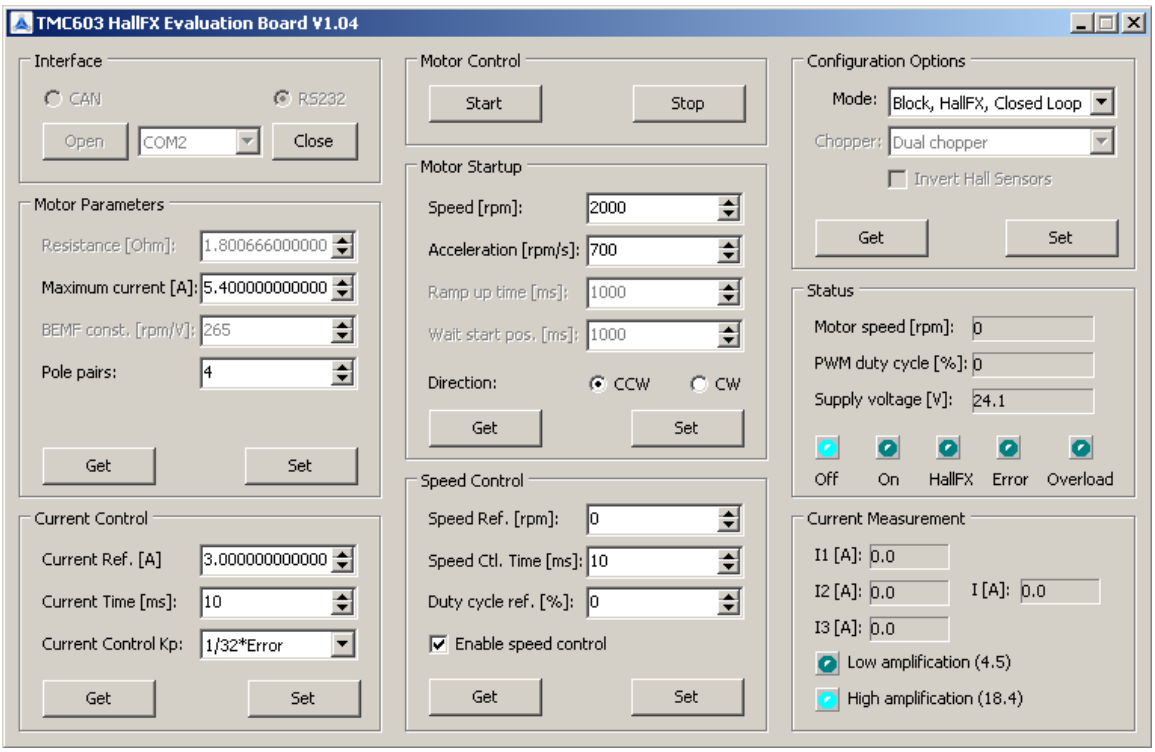

Figure 3: The TMC603 Evaluation Software

4.3 Establishing the connection

Thereafter, start the TMC603 Evaluation Software (Figure 3, page 5) on the PC and select the RS232 interface and the associated COM port that is to be used. If you press the “Open” button the connection will established. The connection establishment was successful if the default settings are read automatically.

4.4 Selecting the operating mode

Then, enter the operating mode “Block, HallFX, Closed Loop”. In this mode the motor will start by using a closed loop ramp up. This means that the closed loop control limits the current. The PWM duty cycle is increased depending on the measured current. Thereafter, the motor will run by using the BLDC back EMF commutation hallFX™. Please keep in mind to press the “Set” button. You can only change the operating mode if the motor is stopped.

4.5 Configuring the motor parameters and settings

In the operating mode “Block, HallFX, Closed Loop” the parameters “Maximum current” and “Pole pairs” are required only. The parameter “Maximum current” is the peak current of the motor. You can find the required data in the datasheet of the motor. In addition, some parameters for closed loop ramp up are necessary. The value “Speed” is the end point of ramp up. The value “Acceleration” is the angle acceleration. The direction can be changed by setting CCW (counter clockwise) or CW (clockwise). Please keep in mind to press the “Set” button. The values in Figure 3 are default parameters.

4.6 Configuring the current and speed controller

Thereafter, you can configure the current controller. The first parameter “Current Ref.” defines the maximum current value for startup. The parameter “Current Time” is the regulation time of the current controller. The last parameter “Current Control Kp” is the proportional gain of the controller. Please take into account the manufacturer’s data of the used BLDC motor. Now, enter the speed reference value (Speed Ref., e.g. 2500rpm) and the speed control time (Speed Ctl. Time). The speed control time is a time duration in ms. In this time the PWM duty cycle counts up or down by a value of 1/16 %. You can change these parameters at any time. Please keep in mind to press the “Set” button.

4.7 Starting the motor

Thereafter, press the “Start” button and the motor will ramp up via closed loop current control and will run by using the BLDC back EMF commutation hallFX™. If the button “Stop” is pressed the motor will stop. In order to change the motor speed you can enter the new speed reference (Speed Ref.) by pressing the button “Set”. Thereupon, the motor will accelerate and decelerate respectively. In addition you can disable the speed control by deactivating the option “Enable speed control”. In this case you can enter the PWM duty cycle (Duty cycle ref.) by pressing the button “Set”. If you disable the speed control, be sure that the “Duty cycle ref” is unequal to zero. Otherwise the motor will stop. Please note if the speed control is disabled, the motor will start without ramp up.

If the motor decelerates after ramp up, be sure that you have entered a speed reference value (Speed Ref.). It is possible that the speed reference value is too low. Also check the speed control time (Speed Ctl. Time). It is possible that the speed control time setting is too low. A third reason is that the current limiting has occurred. So the current reference value (Current Ref.) is too high.

Please take into account that the maximum PWM duty cycle is limited to the value of 93%. This is necessary because the BEMF voltage is incapable of measurement clearly above the PWM duty cycle of 93%.

4.8 Brief instruction

In this chapter you can find a short instruction to start up the motor by using the TMC603 evaluation board. For a detailed description please read the following chapters. In chapter 6.1 (page 12) you can find an overview about all options and parameters.

1. Plug and unplug the jumpers on the evaluation board (Figure 2, page 5)
    a. For sensorless commutation plug the jumpers X212, X213 and X214
    b. For commutation with hall sensors unplug the jumpers X212, X213 and X214
2. Connect the three phase BLDC motor to the evaluation board (X301)

3. Connect the evaluation board via null-modem cable with a RS232 port of the PC
4. Start the PC software EVAL603HallFX.EXE
5. Select the COM port (COM1, COM2, …) and push “Open”
6. Select the mode of operation (Block, HallFX, Closed Loop, …) under “Configuration Options”
    a. For operating mode “Block, HallFX, Open Loop” you need the following parameters
        - “Resistance [Ohm]” of the motor coils
        - “Maximum Current [A]” of the motor
        - “BEMF constant [rpm/V]” of the motor
        - Number of “Pole pairs”
        - “Speed [rpm]” is the starting point of ramp up
        - “Acceleration [rpm/s]” for startup
        - “Ramp up time [ms]” for startup
        - “Wait start pos. [ms]” is the time to turn to the definite start position
        - “Direction” of the rotation (CCW, CW)
        - “Speed Ref. [rpm]” is the reference to change the motor speed
        - “Speed Ctl. Time [ms]” is the time to count up or down the PWM duty cycle
        - “Duty cycle ref. [%]” if speed control is disabled (optional)
    b. For operating mode “Block, HallFX, Closed Loop” you need the following parameters
        - “Maximum Current [A]” of the motor
        - Number of “Pole pairs”
        - “Speed [rpm]” is the end point of ramp up
        - “Acceleration [rpm/s]” for start up
        - “Direction” of the rotation (CCW, CW)
        - “Current Ref. [A]” is the current value for startup
        - “Current Time [ms]” is the regulation time of the current controller
        - “Current Control Kp” is the proportional gain of the controller
        - “Speed Ref. [rpm]” is the reference to change the motor speed
        - “Speed Ctl. Time [ms]” is the time to count up or down the PWM duty cycle
        - “Duty cycle ref. [%]” if speed control is disabled (optional)
    c. For operating mode “Block, Hall Sensor” you need the following parameters
        - “Chopper” mode selection (Low side, High side, Dual chopper)
        - “Invert Hall Sensors” (optional)
        - “Maximum Current [A]” of the motor
        - Number of “Pole pairs”
        - “Direction” of the rotation (CCW, CW)
        - “Speed Ref. [rpm]” is the reference to change the motor speed
        - “Speed Ctl. Time [ms]” is the time to count up or down the PWM duty cycle
        - “Duty cycle ref. [%]” if speed control is disabled (optional)
    d. For operating mode “Sine, HallFX, Closed Loop”
        - Set the same parameters like operating mode “Block, HallFX, Closed Loop”
        - Initialization of sine startup via operating mode “Block, HallFX, Closed Loop” (pls. refer chapter 6.4.4, page 18)
7. Start the motor by pushing the button “Start” under “Motor Control”
8. Change the motor speed
    a. Enter the new speed reference value under “Speed Ref. [rpm]”
    b. Push the button “Set”
9. Change the PWM duty cycle
    a. Enter the new PWM duty cycle reference value under “Duty cycle ref. [%]”
    b. Disable the option “Enable speed control”
    c. Push the button “Set”
10. Stop the motor by pushing the button “Stop” under “Motor Control”

5 The Hardware

5.1 Connectors

The TMC603 evaluation board is equipped with the following connectors:

Connector	Name[1]	Function
Power supply	X201	This is the connector for power supply. The voltage must be between 12V and 48V DC. The positive pole is marked “12V-48V”. The negative pole is marked “GND”. The board is protected against reverse polarity by a diode (from evaluation board version 1.10).
Motor coil output	X301	This is the connector for a three phase BLDC motor. Connect the coils to the pins marked “U”, “V” and “W”.
Hall sensor	X112	This is the connector for optional hall sensors. The first two pins are for power supply of the hall sensors. The voltage is 5V DC. The positive pole is marked “+5V” and the negative pole is marked “GND”. The other three pins are the inputs for hall signals. Connect the hall signals to the pins marked “INPUT1”, “INPUT2” and “INPUT3”.
CAN	X115	This Sub-D connector is a CAN interface for communication to the PC. Additionally you need a Trinamic USB-2-X interface converter which allows easy interfacing the evaluation board to a PC running under Windows 98/2000/XP via the USB Interface. Please see also the USB-2-X manual for a description of the USB-2-X interface converter. The CAN interface uses a baud rate of 500 kbaud. The pin assignment of this connector is as follows: Pin 2 CAN low Pin 3 GND Pin 6 GND Pin 7 CAN high
RS232	X116	This Sub-D connector is a RS232 interface. If the evaluation board is not used with the USB-2-X interface converter, a RS232 plug can be connected here which also allows interfacing the evaluation board to a PC. The RS232 interface uses a baud rate of 115200 baud, eight data bits, one start bit, one stop bit and no parity. Only the pins 2, 3 and 5 are connected. The assignment of this connector is as follows: Pin 2 RxD Pin 3 TxD Pin 5 GND

Table 1: The connectors of the TMC603 evaluation board

[1] You can find the name of the connectors in the TMC603-EVAL schematic.

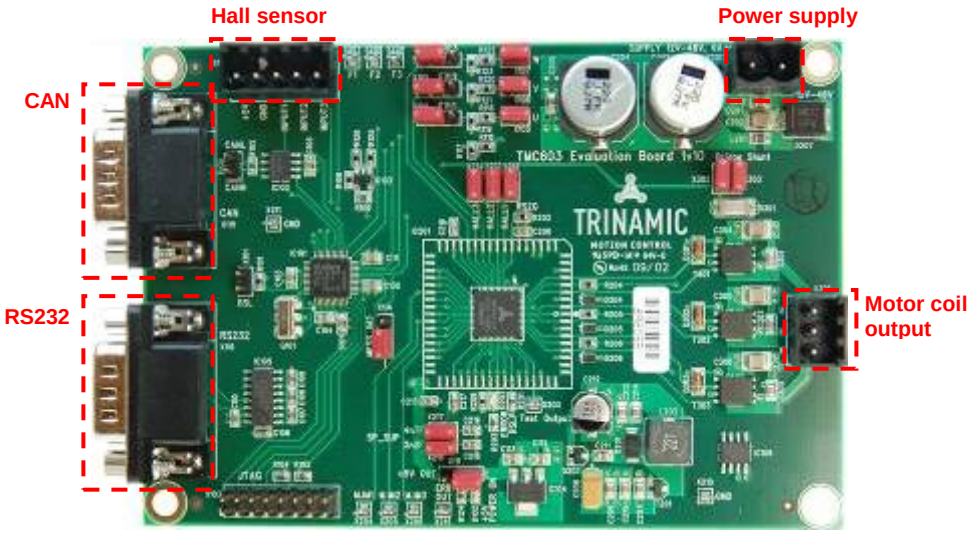

Figure 4: Connectors of the TMC603 evaluation board

5.2 Jumpers and test pins

The TMC603 evaluation board is equipped with the following jumpers and test pins:

Jumper	Name[2]	Function
BSL	X101	If this jumper is plugged, the Bootstrap Loader Mode (BSL) is enabled. The main purpose of BSL Mode is to allow programming/erasing of the Flash and XRAM by using the Infineon USB-2-CAN interface. The default option is to unplug this jumper. **Attention: If you misuse the BSL mode the TMC603 evaluation board firmware and bootloader will erase**.
+5V OUT	X111	The microcontroller and its peripherals needs 5V power supply. This jumper allows to select the 5V power source. You have two options: 1. Integrated 5V linear regulator of the TMC603 (40 mA cont.) (jumper plugged in pin 2 and pin 3) 2. External voltage regulator (IC104) (jumper plugged in pin 1 and pin 2) The default option is the external voltage regulator.
SP_SUP	X216, X217	The external capacitors on this pin controls the commutation spike suppression time for hallFX™. Please refer the TMC603 data sheet for more details. Jumpers unplugged: C_{SPSUP} = 2.2 nF (t_{SPSUP} = 220µs) X216 plugged only: C_{SPSUP} = 2.2 nF + 2.2 nF = 4.4 nF (t_{SPSUP} = 440µs) X217 plugged only: C_{SPSUP} = 2.2 nF + 4.7 nF = 6.9 nF (t_{SPSUP} = 690µs) X216 and X217 plugged: C_{SPSUP} = 2.2 nF + 2.2 nF + 4.7 nF = 9.1 nF (t_{SPSUP} = 910µs)

Table 2: The jumpers of the TMC603 evaluation board

[2] You can find the name of the jumpers in the TMC603-EVAL schematic.

Jumper	Name[3]	Function
U, V, W	X105, X106, X107	At these jumpers you can measure phase currents and voltages of the BLDC motor.
Filt1, Filt2, Filt3	X108, X109, X110	The microcontroller includes an Analog-to-Digital Converter (ADC) with eight analog input channels. The input signals of the ADC channels 5, 6 and 7 are selectable. You have two options: 1. filtered coil voltages provided by the TMC603 (jumpers plugged in pin 1 and pin 2) 2. unfiltered coil voltages provided by a resistor divider (jumpers plugged in pin 2 and pin 3) The default option are the filtered coil voltages provided by the TMC603.
F1, F2, F3	X207, X208, X209	Here you can measure the filtered voltages Filt1, Filt2 and Filt3 of the coils directly provided by the TMC603.
HALL1, HALL2, HALL3	X212, X213, X214	You must plug these jumpers to use the TMC603 evaluation board with the BLDC back EMF commutation hallFX™. Unplug these jumpers to use the hall sensors.
MESS_IM3	X114	The input signal of the ADC channel 3 is also selectable. You have two options: 1. current measurement output CUR3 of the TMC603 (jumper plugged in pin 1 and pin 2) 2. shunt based current measurement with a difference amplifier (jumper plugged in pin 2 and pin 3) The default option is the current measurement output CUR3 of the TMC603. Please note that the current measurement outputs CUR1 and CUR2 are connected directly to the ADC channels 0 and 1.
M.IM1, M.IM2, M.IM3	X204, X205, X206	Here you can measure the currents CUR1, CUR2 and CUR3 of the coils directly provided by the TMC603.
Test Output	X203	The test output is reserved for manufacturing test. Please refer the TMC603 data sheet for more details.
ERROUT	X215	Here you can measure the error output signal of the TMC603. The TMC603 has three different sources for signaling an error: 1. Undervoltage of the low side supply 2. Undervoltage of the charge pump 3. Short to GND detector Upon any of these events the error output is pulled low.
Bridge Shunt	X302, X303	You must plug these jumpers to bypass the low end resistor. You can unplug these jumpers for other applications like a shunt based current measurement with a difference amplifier. The default option is to bypass the low end resistor.

Table 3: The jumpers of the TMC603 evaluation board (continued)

[3] You can find the name of the jumpers in the TMC603-EVAL schematic.

5.3 Status Signals

The TMC603 evaluation board provides two status LEDs. The green LED (D102) lights up if the power supply is working. The red LED (D203) lights up if an error is occurred by undervoltage of VLS or VCP as well as by short to ground of the power MOS half bridges.

5.4 Dimensions

The mechanical dimensions of the TMC603 evaluation board are shown in Figure 5, page 11. This evaluation board has four layers: top side, GND plane, power plane and bottom side. The thickness is ca. 1.67 mm. The size of the board incl. components is ca. 15.4 mm. The diameter of the boreholes is 4.6 mm.

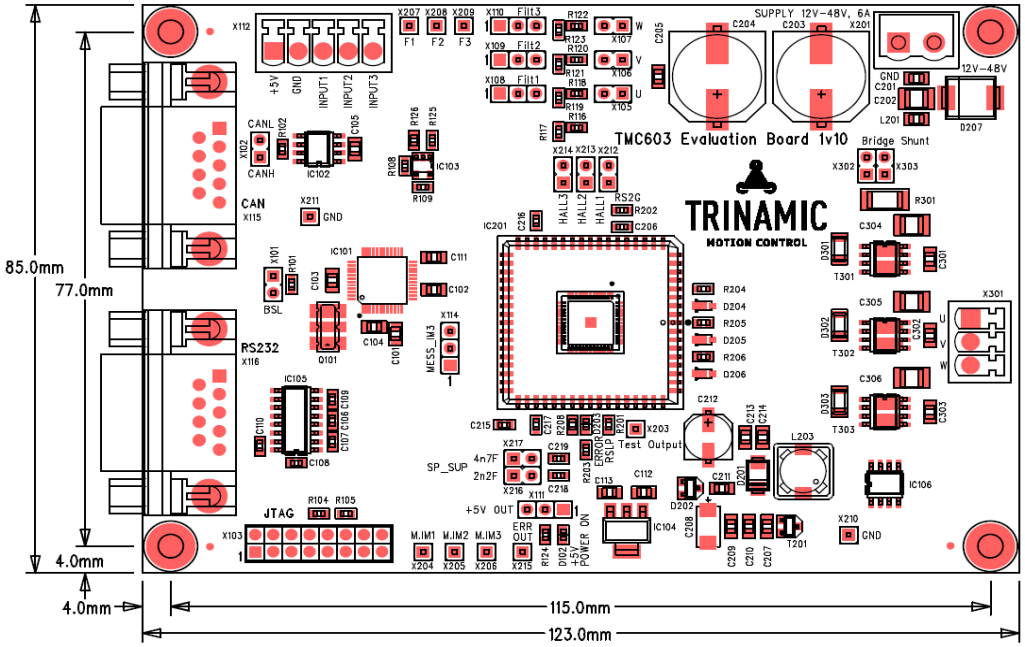

Figure 5: Dimensions of the TMC603 evaluation board

5.5 Compatible CPU types

In case, you search for a firmware compatible CPU, the following types are available from Infineon:

SAF-XC886CLM-8FFA 5V AC
SAK-XC886CLM-8FFA 5V AC
SAF-XC886CLM-8FFI 5V AC
SAK-XC886CLM-8FFI 5V AC
SAK-XC886CM-8FFI 5V AC
SAF-XC886CM-8FFI 5V AC

A later version of the board will use a more powerful 32 bit CPU, which need different firmware.

6 The PC Software

PC software to operate the TMC603 evaluation board is supplied on the TMC TechLibCD or can be downloaded at http://www.trinamic.com. The program can be used with Windows 98, Windows 2000 and Windows XP. To install it, just copy the file "EVAL603HallFX.EXE" to the hard disk of your PC. To run the program, double click the file.

6.1 Overview

After starting the software, the main window will be shown (Figure 3). The PC software is divided into several parts.

Option	Function
Interface	Here you can establish a connection via CAN interface or RS232 interface.
CAN	Here you can select the CAN interface.
RS232	Here you can select the RS232 interface.
Open	Press the "Open" button and the connection will established.
Close	Press the "Close" button and the connection will closed.
Motor Control	Here you can start and stop the motor.
Start	Press the "Start" button and the motor will run.
Stop	Press the "Stop" button and the motor will stopped.
Configuration Options	Here you can select the operating mode, the chopper mode and the option "Invert Hall Sensors". You can only change the operating mode if the motor is stopped.
Mode	Here you can select the operating mode. There are currently three modes: 1. Block, HallFX, Open Loop This mode is the sensorless block commutation with hallFX™ and open loop current control. In this mode the motor will start with block commutation by using an open loop ramp up. This means that the PWM duty cycle is increased in a definite time. Then, the motor will run by using the BLDC back EMF commutation hallFX™. 2. Block, HallFX, Closed Loop This mode is the sensorless block commutation with hallFX™ and closed loop current control. In this mode the motor will start with block commutation by using a closed loop ramp up. This means that the closed loop control limits the current. The PWM duty cycle is increased depending on the measured current. Thereafter, the motor will run by using the BLDC back EMF commutation hallFX™. 3. Block, Hall Sensor This mode is the block commutation with hall sensors. In this mode the motor runs with hall sensors so that no ramp up procedure is necessary. You can additionally select the chopper mode and the option "Invert Hall Sensors". 4. Sine, HallFX, Closed Loop This mode is the sensorless block commutation with hallFX™ and closed loop current control. In this mode the motor will start with sinusoidal commutation by using a closed loop ramp up. This means that the closed loop control limits the current. The PWM duty cycle is increased depending on the measured current. Thereafter, the motor will run by using the BLDC back EMF commutation hallFX™.

Table 4: Several parts of PC software

Option	Function
Chopper	Here you can select the chopper mode. This option is available in “Block, Hall Sensor” mode only. The chopper frequency is 20kHz. 1. Low side chopper mode In this chopper mode the low side drivers are chopped only. 2. High side chopper mode In this chopper mode the high side drivers are chopped only. 3. Dual chopper mode Both, the high side drivers and the low side drivers are chopped with the same signal. The dual chopper mode is required for HallFX.
Invert Hall Sensors	This option can be selected optionally if the signals of the hall sensors are inverted to the hallFX™ signals. If this option is unused the firmware of the TMC603 evaluation board will configured the correct setting automatically. This option is available in “Block, Hall Sensor” mode only.
Motor Parameters	In these input boxes you can enter the required motor parameters. You can find the required data in the datasheet of the motor.
Resistance	This parameter is the resistance of the motor coils.
Maximum current	This parameter is the peak current of the motor.
BEMF const.	This parameter is the BEMF constant of the motor. Please take into account that the unit of the BEMF constant is in rpm/V
Pole pairs	This is the number of pole pairs of the motor.
Motor Startup	Here you can enter the parameters for motor start up.
Speed	If you selected the operating mode “Block, HallFX, Open Loop”, the value “Speed” is the starting point of ramp up. If you selected the operating mode “Block, HallFX, Closed Loop”, the value “Speed” is the end point of ramp up.
Acceleration	This value is the angle acceleration for startup.
Ramp up time	The ramp up time is the time duration of startup.
Wait start pos.	This value is the time before ramp up. In this time the rotor turns to the definite start position.
Direction	This is the rotating direction of the motor. The direction can be changed by setting CCW (counter clockwise) or CW (clockwise).
Status	This option shows display fields with actual values and status flags.
Motor speed	The field “Motor speed “displays the actual speed of the motor.
PWM duty cycle	The field “PWM duty cycle” displays the actual PWM duty cycle.
Supply voltage	The filed “Supply voltage” displays the actual power supply voltage.
Off	The status flag “Off” lights up if the motor is stopped.
On	The status flag “On” lights up if the motor is started.
HallFX	The status flag “HallFX” lights up if the motor is run by using the sensorless BLDC back EMF commutation hallFX™

Table 5: Several parts of PC software (continued)

Option	Function
Error	The status flag “Error” lights up and the motor will stopped if an error has occurred. The TMC603 has three different sources for signaling an error: 1. Undervoltage of the low side supply 2. Undervoltage of the charge pump 3. Short to GND detector In addition the status flag “Error” lights up if you try to ramp up the motor with sine startup and no initialization has been done.
Overload	The status flag “Overload” lights up if a current overload is detected. In this case the PWM duty cycle will be decreased. You can define the current limiting by setting the parameter “Maximum current”.
Current Control	Here you can configure the current controller. Please take into account the manufacturer’s data of the used BLDC motor.
Current Ref.	The current reference value defines the maximum current value for startup.
Current Time	The parameter “Current Time” is the regulation time of the current controller.
Current Control Kp	The parameter “Current Control Kp” is the proportional gain (Kp) of the controller.
Speed Control	In this field you can modify the speed control parameters.
Speed Ref.	The speed reference value defines the actual motor speed.
Speed Ctl. Time	The speed control time is given in milliseconds (ms). In this time the PWM duty cycle counts up or down by a value of 1/16 %.
Duty Cycle Ref.	If the speed control is disabled, the duty cycle reference value defines the actual PWM duty cycle.
Enable speed control	If this option is selected the speed control is enabled. You can disable the speed control by deactivating this option. In this case you can enter the PWM duty cycle (Duty cycle ref.) by pressing the “Set” button. If you disable the speed control, be sure that the “Duty Cycle Ref.” is unequal to zero. Otherwise the motor will stop. Please note if the speed control is disabled, the motor will start without ramp up.
Current Measurement	These display fields show the actual currents of the 3 phase BLDC motor and the overall current. The status flags display the actual amplification of the internal amplifier of TMC603.
I1	This display field shows the actual current (I_{1RMS}) of the motor phase U.
I2	This display field shows the actual current (I_{2RMS}) of the motor phase V.
I3	This display field shows the actual current (I_{3RMS}) of the motor phase W.
I	This display field shows the actual overall current (I_{RMS}) of the motor.
Low amplification	The status flag “Low amplification (4.5)” lights up if the actual amplification of the internal amplifier of TMC603 is set to low.
High amplification	The status flag “Low amplification (18.4)” lights up if the actual amplification of the internal amplifier of TMC603 is set to high.
Get/Set buttons	By pressing these buttons the parameters will received and transmitted respectively.
Get	All parameters may be read by pressing the respective “Get” button.
Set	Press the “Set” button to send the parameters to the evaluation board.

Table 6: Several parts of PC software (continued)

6.2 Establishing the connection

You can establish a connection to the PC via RS23 interface and via CAN interface. In the following these options shall be described.

6.2.1 Connection via RS232 interface

If you use the RS232 interface you need no additional hardware. Before starting the software, the evaluation board should be connected to an RS232 interface of your PC using a null modem cable. Then, make sure that the evaluation board is supplied with power. Thereafter, start the PC software by double clicking the file "EVAL603HallFX.EXE". Then, select the RS232 interface and the associated COM port that is to be used. If you press the "Open" button the connection will established. After that, all default parameters may be read automatically.

Figure 6: Connection via RS232

6.2.2 Connection via CAN interface

If you use the CAN interface you need the TRINAMIC USB-2-X interface converter to function correctly. Before running the program, install the TRINAMIC USB-2-X interface converter (pls. Refer USB-2-X manual) and attach the TMC603 evaluation board to it. Then, make sure that the evaluation board is supplied with power. Thereafter, start the PC software by double clicking the file "EVAL603HallFX.EXE". Then, select the CAN interface and the associated CAN device that is to be used. If you press the "Open" button the connection will established. After that, all default parameters may be read automatically.

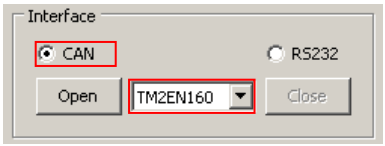

Figure 7: Connection via CAN

6.3 Selecting the operating mode

If the connection is established you can select the operating mode by pressing the pull-down menu. The several modes are "Block, HallFX, Open Loop", "Block, HallFX, Closed Loop", "Block, Hall Sensor" and "Sine, HallFX, Closed Loop". You can only change the operating mode if the motor is stopped. If you select the "Block, Hall Sensor" mode you can additionally select the chopper mode. Three chopper modes are available (Dual chopper, Low side chopper, High side chopper). Please press the "Set" button to send these data to the evaluation board.

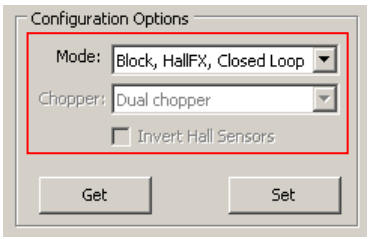

Figure 8: Configuration options

6.3.1 The operating mode "Block, HallFX, Open Loop"

The first mode is the sensorless block commutation with hallFX™ and open loop current control. In this mode the motor will start with block commutation by using an open loop ramp up. This means that the PWM duty cycle is increased in a definite time. Thereafter, the motor will run by using the BLDC back EMF commutation hallFX™.

6.3.2 The operating mode "Block, HallFX, Closed Loop"

The second mode is the sensorless block commutation with hallFX™ and closed loop current control. In this mode the motor will start with block commutation by using a closed loop ramp up. This means that the closed loop control limits the current. The PWM duty cycle is increased depending on the measured current. Thereafter, the motor will run by using the BLDC back EMF commutation hallFX™.

6.3.3 The operating mode "Block, Hall Sensor"

The third mode is the block commutation with hall sensors. In this mode the motor runs with hall sensors so that no ramp up procedure is necessary. You can additionally select the chopper mode. Three chopper modes are available: Low side chopper, high side chopper and dual chopper (default).

If you select the low side chopper mode, the low side drivers are chopped only. In the high side chopper mode the high side drivers are chopped only. If you select the dual chopper mode, the high side drivers and the low side drivers are chopped with the same signal. The option “Invert Hall Sensors” can be selected optionally if the signals of the hall sensors are inverted to the hallFX™ signals. If this option is unused the firmware of the TMC603 evaluation board will configured the correct setting automatically.

6.3.4 The operating mode “Sine, HallFX, Closed Loop”

The last mode is also a sensorless block commutation with hallFX™ and closed loop current control. In this mode the motor will start with sinusoidal commutation by using a closed loop ramp up. This means that the closed loop control limits the current. The PWM duty cycle is increased depending on the measured current. Thereafter, the motor will run by using the BLDC back EMF commutation hallFX™.

6.4 Configuring the parameters and settings

Depending on the selected operating mode, several parameters and settings should be configured before running the motor. Other settings are disabled because these options are unnecessary. In the following these required options shall be described.

6.4.1 Configuration of operating mode “Block, HallFX, Open Loop”

Before starting up the BLDC motor, some information about the motor are required (Figure 9). The first parameter is the resistance of the motor coils. The second parameter is the maximum current. This is the peak current of the motor. The last parameters are the pole pair number and the BEMF constant of the motor. Please take into account that the unit of the BEMF constant is in rpm/V.

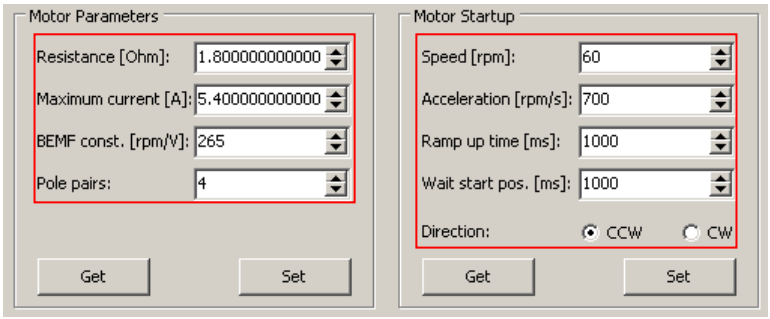

Figure 9: Motor parameters and motor startup parameters (“Block, HallFX, Open Loop”)

Furthermore some parameters for open loop ramp up are necessary (Figure 9). The value “Speed” is the starting point of ramp up. The value “Acceleration” is the angle acceleration for startup. The ramp up time is the duration of ramp up. The value “Wait start pos.” is the time before ramp up. In this time the rotor turns to the definite start position. The direction can be changed by setting CCW (counter clockwise) or CW (clockwise).

Now, enter the speed reference value (Speed Ref.) and the speed control time (Speed Ctl. Time). The speed control time is a time duration in ms. In this time the PWM duty cycle counts up or down by a value of 1/16 %. You can change these parameters at any time. Please keep in mind to press the “Set” button. Thereafter, press the “Start” button and the motor will ramp up via open loop current control and will run by using the BLDC back EMF commutation hallFX™. The motor will stop, when the button “Stop” is pressed.

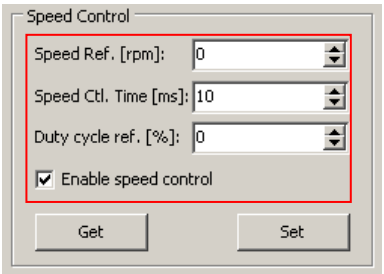

Figure 10: Speed control options

In order to change the motor speed you can enter the new speed reference (Speed Ref.) by pressing the button “Set”. Thereupon, the motor will accelerate and decelerate respectively. In addition you can disable the speed control by deactivating the option “Enable speed control” (Figure 10). In this case you can enter the PWM duty cycle (Duty cycle ref.) by pressing the button “Set”. If you disable the

speed control, be sure that the “Duty cycle ref” is unequal to zero. Otherwise the motor will stop. Please note if the speed control is disabled, the motor will start without ramp up.

Please take into account that the maximum PWM duty cycle is limited to the value of 93%. This is necessary because the BEMF voltage is incapable of measurement clearly above the PWM duty cycle of 93%.

6.4.2 Configuration of operating mode “Block, HallFX, Closed Loop”

In this mode the parameters “Maximum current” and “Pole pairs” are required only. In addition, some parameters for closed loop ramp up are necessary. The value “Speed” is the end point of ramp up. The value “Acceleration” is the angle acceleration for startup. The direction can be changed by setting CCW or CW. (Figure 11)

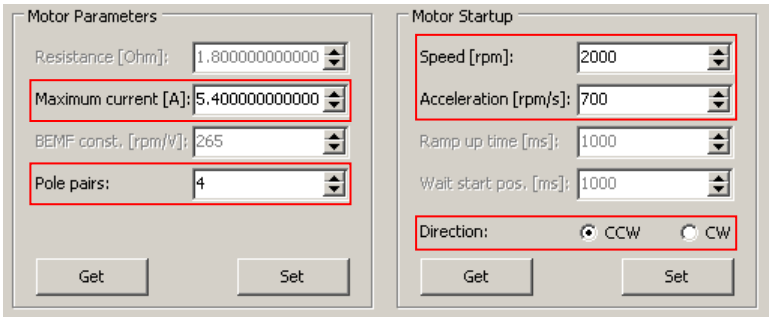

Figure 11: Motor parameters and motor startup parameters (“Block, HallFX, Closed Loop”)

Thereafter, you can configure the current controller. The first parameter “Current Ref.” defines the maximum current value for startup. The parameter “Current Time” is the regulation time of the current controller. The last parameter “Current Control Kp” is the proportional gain of the controller. Now, enter the speed reference value (Speed Ref.) and the speed control time (Speed Ctl. Time). The speed control time is given in milliseconds (ms). In each time interval the PWM duty cycle counts up or down by a value of 1/16 %. You can change these parameters at any time. Please keep in mind to press the “Set” button.

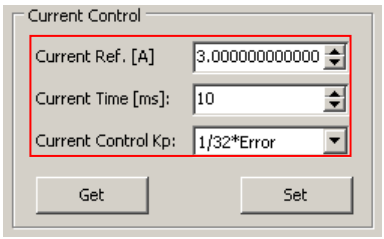

Figure 12: Current control options

Thereafter, press the “Start” button and the motor will ramp up via closed loop current control and will run by using the BLDC back EMF commutation hallFX™. When pressing the button “Stop”, the motor will stop. In order to change the motor speed you can enter the new speed reference (Speed Ref.) by pressing the button “Set” (Figure 10, page 16). Thereupon, the motor will accelerate and decelerate respectively.

In addition you can disable the speed control by deactivating the option “Enable speed control” (Figure 10, page 16). In this case you can enter the PWM duty cycle (Duty cycle ref.) by pressing the button “Set”. If you disable the speed control, be sure that the “Duty cycle ref” is unequal to zero. Otherwise the motor will stop. Please note if the speed control is disabled, the motor will start without ramp up.

Please take into account that the maximum PWM duty cycle is limited to the value of 93%. This is necessary because the BEMF voltage is incapable of measurement clearly above the PWM duty cycle of 93%.

6.4.3 Configuration of operating mode “Block, Hall Sensor”

In this mode no ramp up procedure is necessary. Only the parameters “Maximum current” and “Pole pairs” are required (Figure 13). The direction can be changed by setting CCW or CW. If the required parameters are defined, enter the speed reference value (Speed Ref.) and the speed control time (Speed Ctl. Time). The speed control time is given in milliseconds (ms). In each time interval, the

PWM duty cycle counts up or down by a value of 1/16 %. You can change these parameters at any time. Please keep in mind to press the “Set” button (Figure 10, page 16).

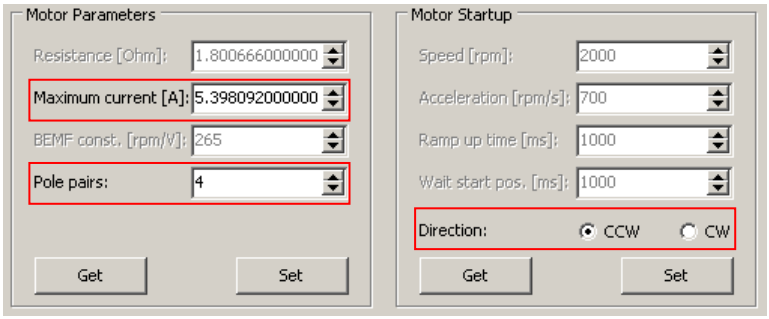

Figure 13: Motor parameters and motor startup parameters (“Block, Hall Sensor”)

Thereafter, press the “Start” button and the motor will accelerate up to the defined speed reference (Speed Ref.). Pressing the button “Stop” stops the motor. In order to change the motor speed you can enter the new speed reference (Speed Ref.) by pressing the button “Set” (Figure 10, page 16). Thereupon, the motor will accelerate and decelerate respectively.

In addition you can disable the speed control by deactivating the option “Enable speed control” (Figure 10, page 16). In this case you can enter the PWM duty cycle (Duty cycle ref.) by pressing the button “Set”. If you disable the speed control, be sure that the “Duty cycle ref” is unequal to zero. Otherwise the motor will stop.

6.4.4 Configuration of operating mode “Sine, HallFX, Closed Loop”

Before starting up the BLDC motor with sinusoidal commutation, an initialization is required. Please start the motor in operating mode “Block, HallFX, Closed Loop” like described in chapter 6.4.2 to initialize the sine startup. If the motor is running, then stop the motor by pressing the “Stop” button. Thereafter select the operating mode “Sine, HallFX, Closed Loop” and start the motor again by pressing the “Start” button. Now, the motor is ramping up with sinusoidal commutation. After startup the motor will run by using the BLDC back EMF commutation hallFX™.

If you try to ramp up the motor without initialization of sine startup, the status flag “Error” lights up. In this case press the “Stop” button and start the motor in operating mode “Block, HallFX, Closed Loop” like described in chapter 6.4.2 to initialize the sine startup.

Please note if you change the motor parameters, motor startup parameters (Figure 11) or the current control options (Figure 12) a new initialization for sine startup is required.

In order to change the motor speed you can enter the new speed reference (Speed Ref.) by pressing the button “Set” (Figure 10, page 16). Thereupon, the motor will accelerate and decelerate respectively. In addition you can disable the speed control by deactivating the option “Enable speed control” (Figure 10, page 16). In this case you can enter the PWM duty cycle (Duty cycle ref.) by pressing the button “Set”. If you disable the speed control, be sure that the “Duty cycle ref” is unequal to zero. Otherwise the motor will stop. Please note if the speed control is disabled, the motor will start without ramp up.

6.5 An example

In this example it is assumed that the QMot Motor QBL4208-41-04-006 is connected to the motor output connector. The evaluation board is connected to an RS232 interface of the PC by using a null modem cable. The board is supplied with 24V (DC).

At first, we would like to use the sensorless block commutation with hallFX™ to run the BLDC motor. Please check if the jumpers X212, X213 and X214 are plugged. Then start the PC software and establish a connection between the evaluation board and the PC.

Thereafter set the operating mode to "**Block, HallFX, Closed Loop**" to ramp up with block commutation and closed loop current control. Then enter the parameters as shown in Figure 14. Please keep in mind to press the "Set" buttons. Thereafter, press the "Start" button and the motor will ramp up via closed loop current control and will run by using the sensorless BLDC back EMF commutation hallFX™.

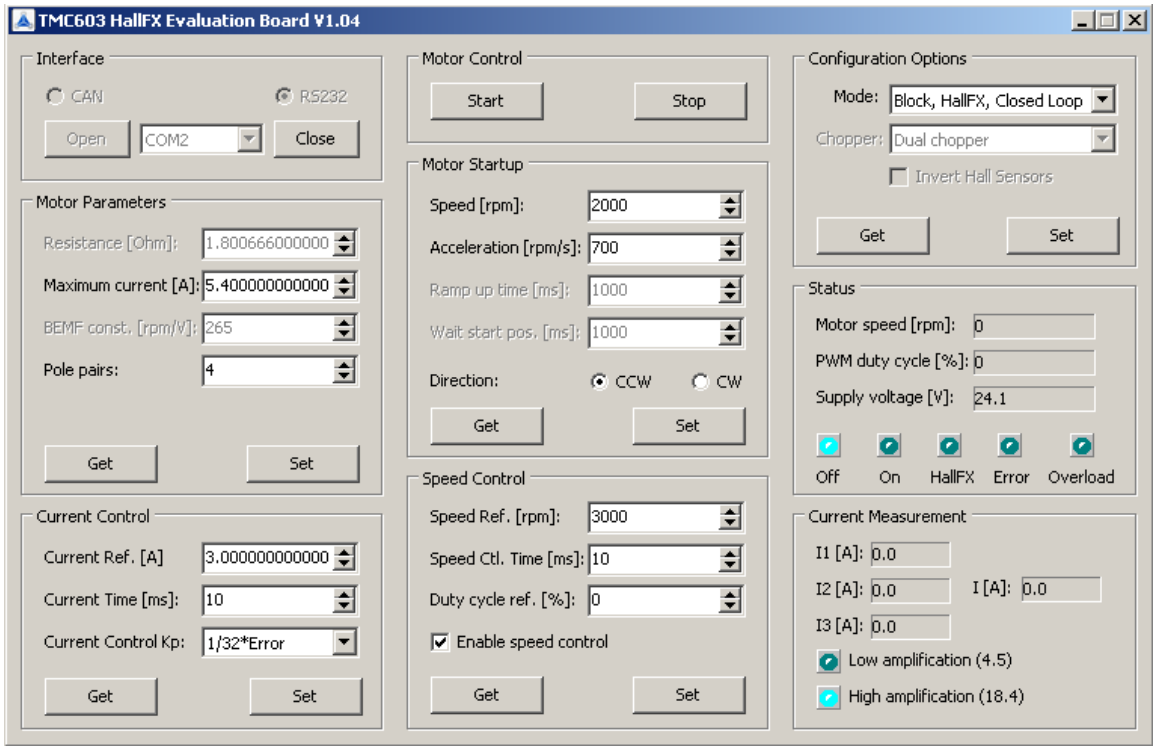

Figure 14: Parameter settings for closed loop current control (Example: QMot QBL4208-41-04-006)

After startup, the motor accelerate up to the defined speed reference value (Speed Ref.). In this example the speed reference value is set to 3000rpm. The PWM duty cycle is about 62 % dependent on the mechanical load.

Now, we would like to disable the speed control. Please deactivate the option "Enable speed control" and set the duty cycle reference value (Duty Cycle Ref.) to 62 %. Then press the "Set" button. The motor will run without speed control. The PWM duty cycle is fixed. You can change the PWM duty cycle by setting a new duty cycle reference value (Duty Cycle Ref.).

If you would like to start the BLDC motor with sinusoidal commutation, an initialization for sine startup is required. Select the operating mode "Block, HallFX, Closed Loop" and enter the parameters as shown in Figure 14. Please check the option "Enable speed control". The speed control should be enabled. If the speed control is disabled, the motor will start without ramp up. Please keep in mind to press the "Set" buttons. Thereafter, press the "Start" button and the motor will ramp up with block commutation. If the motor is running the initialization is successful. Then stop the motor by pressing the "Stop" button und select the operating mode "**Sine, HallFX, Closed Loop**". Thereafter, press the "Start" button and the motor will ramp up with sinusoidal commutation and will run by using the sensorless BLDC back EMF commutation hallFX™.

The initialization for sine startup is not required if you have already started the motor with the same settings in operating mode “Block, HallFX, Closed Loop”.

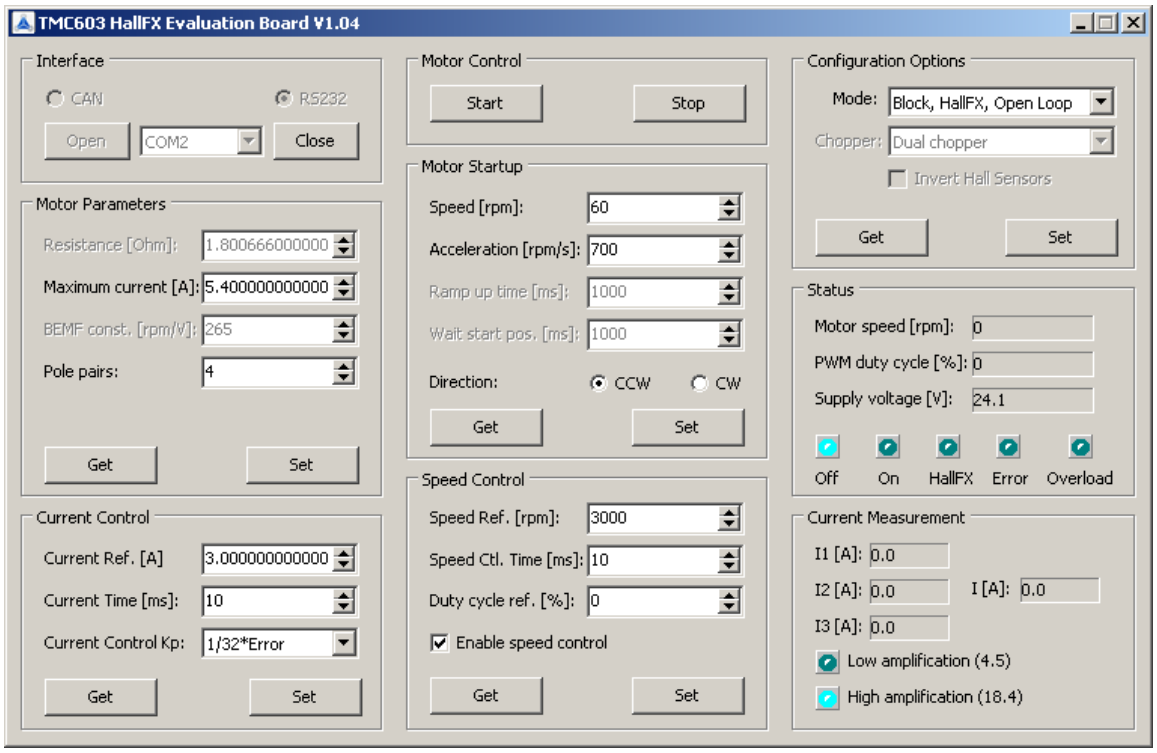

Figure 15: Parameter settings for open loop current control (Example: QMot QBL4208-41-04-006)

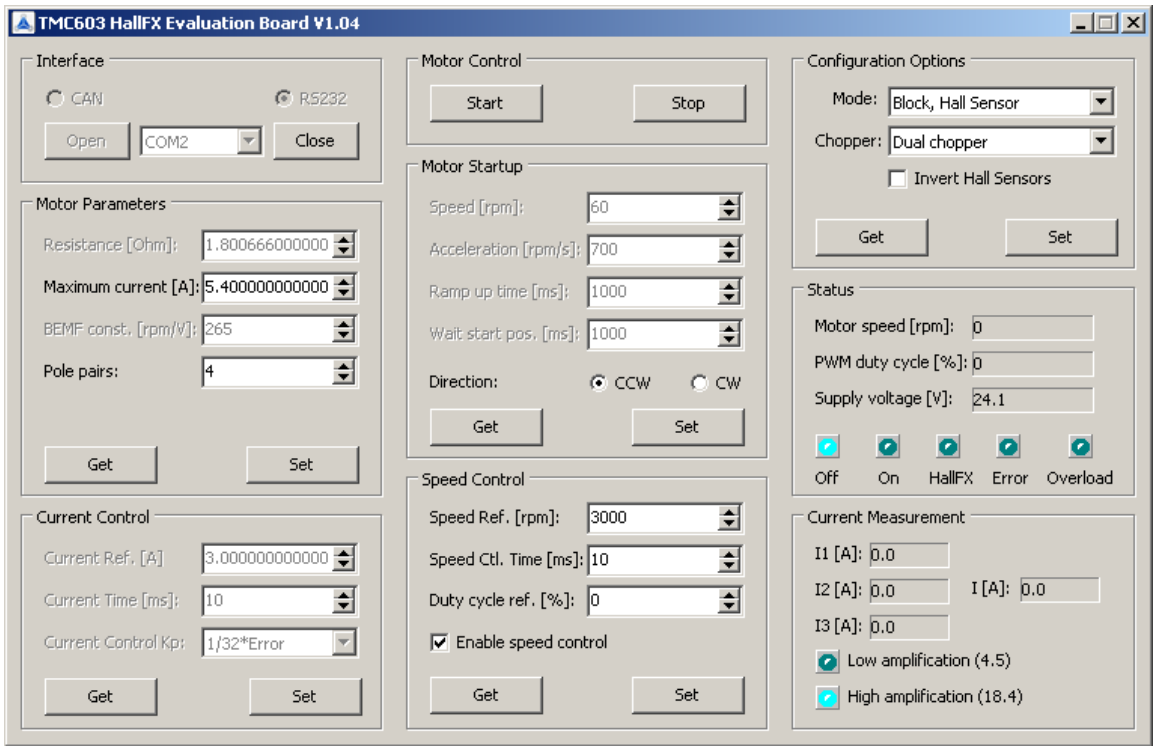

Figure 16: Parameter settings for hall sensors (Example: QMot QBL4208-41-04-006)

You can also start the BLDC motor with open loop current control. Please check if the jumpers X212, X213 and X214 are plugged. Select the operating mode "**Block, HallFX, Open Loop**" and enter the parameters as shown in Figure 15 (page 20). Please keep in mind to press the "Set" buttons. Thereafter, press the "Start" button and the motor will ramp up via open loop current control and will run by using the sensorless BLDC back EMF commutation hallFX™. If the motor is not running, the parameters should be calculated experimentally.

For using hall sensors, please check if the jumpers X212, X213 and X214 are not plugged. Then plug the hall sensor connector to X112. Thereafter select the operating mode "**Block, Hall Sensor**" and enter the parameters as shown in Figure 16 (page 20). Please keep in mind to press the "Set" buttons. Then, press the "Start" button and the motor accelerate up to the defined speed reference value (Speed Ref.).

In addition you can select the chopper mode. Three chopper modes are available: Low side chopper, high side chopper and dual chopper (default). If you select the low side chopper mode, the low side drivers are chopped only. In the high side chopper mode the high side drivers are chopped only. If you select the dual chopper mode (default), the high side drivers and the low side drivers are chopped with the same signal. The option "Invert Hall Sensors" can be selected optionally if the signals of the hall sensors are inverted to the hallFX™ signals. If this option is unused the firmware of the TMC603 evaluation board will configured the correct setting automatically.

In order to disable the speed control, please deactivate the option "Enable speed control" and set the PWM duty cycle reference value (Duty Cycle Ref.). Then press the "Set" button. The motor will run without speed control. You can change the PWM duty cycle by setting a new duty cycle reference value (Duty Cycle Ref.).

7 The Firmware

7.1 Updating the firmware

The TMC603 evaluation software enables to modify the motor and startup parameters and to control the motor speed. However to update the firmware of the TMC603 evaluation board, the TMCL IDE is required. The TMCL IDE is supplied on the TMC TechLibCD or can be downloaded at http://www.trinamic.com. To install it, just copy the file “TMCL.EXE” to the hard disk of your PC. To run the program, double click the file.

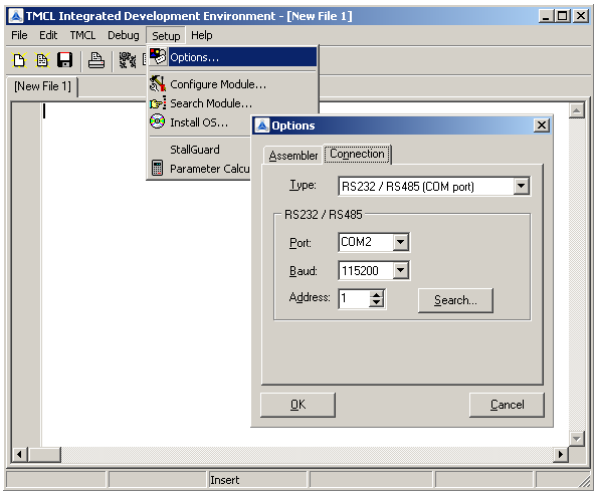

Figure 17: Connection options

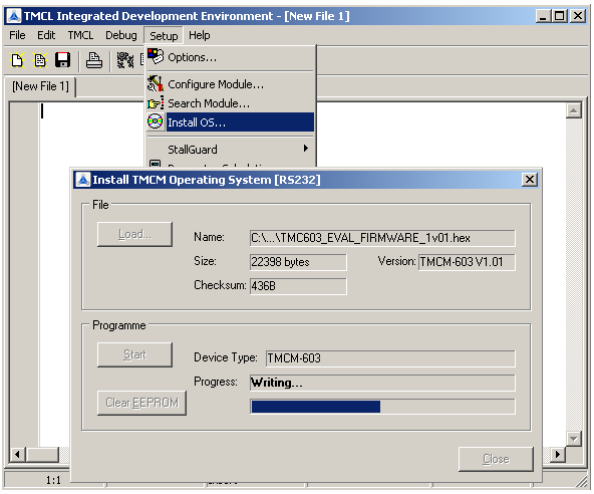

Figure 18: Install operating system

At first, open the connection options (Figure 17). Here you should select “RS232/RS485 (COM port)” and the COM port that is to be used. Set the baud rate to 115200 baud. The module address is 1.

Now, open the install OS window (Figure 18). At first, load the new firmware file by pressing the “Load” button. The file is then checked if it is a TMCL firmware file. Its device type and version number will be displayed. Then, press the “Start” button to program the new firmware into the module. Please make sure that there will be no power cut or cut of the serial connection during the programming process. The program checks if the device type in the firmware file and the device type of the evaluation board are identical. An error message will be displayed if this is should not be the case. If everything is okay, the new firmware will be programmed into the evaluation board and verified afterwards. The programming progress is shown by the status bar.

After the programming process, you can close the TMCL IDE. Then, start the TMC603 evaluation software to run the motor.

8 List of Figures

9 List of Tables

10 References

TMC603 datasheet	(see http://www.trinamic.com)
TMC603-EVAL schematics	(see http://www.trinamic.com)
USB-2-X manual	(see http://www.trinamic.com)
TMCL Reference and Programming Manual	(see http://www.trinamic.com)

11 Revision History

11.1 Documentation Revision

Version	Date	Author	Description
0.90	24-Oct-08	MW	Initial Release
0.91	4-Nov-08	MW	Mechanical dimensions added
1.00	18-Feb-09	MW	Chapter 6 updated, chapter 7 added, 1st published version
1.01	14-Apr-09	MW	Chapter 4 updated, chapter 6 updated, modification note added

Table 7 : Documentation Revisions

11.2 Firmware Revision

Version	Date	Author	Description
1.00	29-Jan-09	MW	Initial Release
1.01	16-Feb-09	MW	Errors fixed
1.02	17-Feb-09	MW	PWM duty cycle limited in hallFX™ mode
1.03	05-Mrz-09	MW	Error in the current regulation resolved
1.04	03-Apr-09	MW	Sinusoidal commutation ramp up added, Option “Enable Speed Control” added

Table 8: Firmware Revisions

11.3 PC Software Revision

Version	Date	Author	Description
1.00	7-Nov-08	MW	Initial Release
1.01	26-Nov-08	MW	Current measurement added
1.02	19-Feb-09	MW	Current control and configuration options added
1.03	23-Feb-09	MW	Number of COM ports increased
1.04	26-Mrz-09	MW	Sinusoidal commutation ramp up added, Option “Enable Speed Control” added

Table 9: PC Software Revisions

11.4 Hardware Revision

Version	Date	Author	Description
1.00	29-Jan-09	MW	Initial Release
1.10	17-Feb-09	MW	Reverse voltage protection added, changeable C_{SP_SUP} added

Table 10: Hardware Revisions

Note:
For the first TMC603 evaluation boards (version 1.00 and 1.10), the current measurement is sub-optimal due to a PCB layout mistake. This leads to a noise signal on the current measurement signals of the TMC603. It is fixed by a wire on the first evaluation boards. Some very first boards have been delivered without the fixing wire. Actual boards will be delivered with this fixing wire.

In the PCB layout the track width between the source connector of the N-Channel MOSFET transistors (T301, T302, T303) and the shunt resistor R301 is dimensioned too small (Figure 19). This leads to a very high resistance in the ratio of the drain-source on-state resistance $R_{DS(on)}$. If the resistance of the track is higher than 1% of the $R_{DS(on)}$, it will have an effect on the current measurement signals. The shunt resistor R301 will also have an effect on the current measurement, although the shunt resistor is bypassed by the jumpers X302 and X303.

If you use one of the first evaluation boards without the fixing wire, please connect on the bottom side the source connector of the N-Channel MOSFET transistors (T301, T302, T303) to ground as shown in Figure 20 by using a wide wire. The width should be more than 0.85 mm.

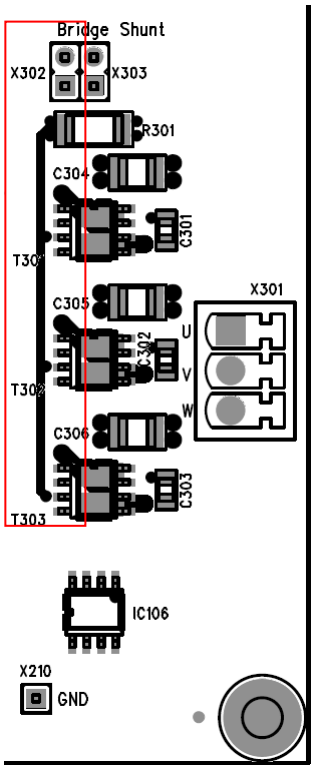

Figure 19: Layout detail of TMC603-Eval

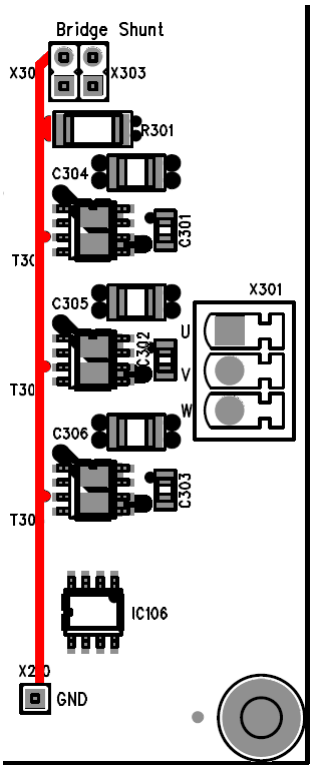

Figure 20: Detail of layout shows the solution

Layout consideration:
For your own layout, please take into account that the track width is wide enough between the source connectors of the N-Channel MOSFET transistors and ground. The resistance of this track should be less than 1% of the drain-source on-state resistance $R_{DS(on)}$ of the N-Channel MOSFET transistors. In an example this shall be explain. If the resistance $R_{DS(on)}$ is 50mΩ, the maximum resistance of the track should be less than 0.5mΩ. The optimum solution is to connect the source of the N-Channel MOSFET transistors to a ground plain.