

100 W 3-phase inverter for BLDC sensorless motor evaluation board

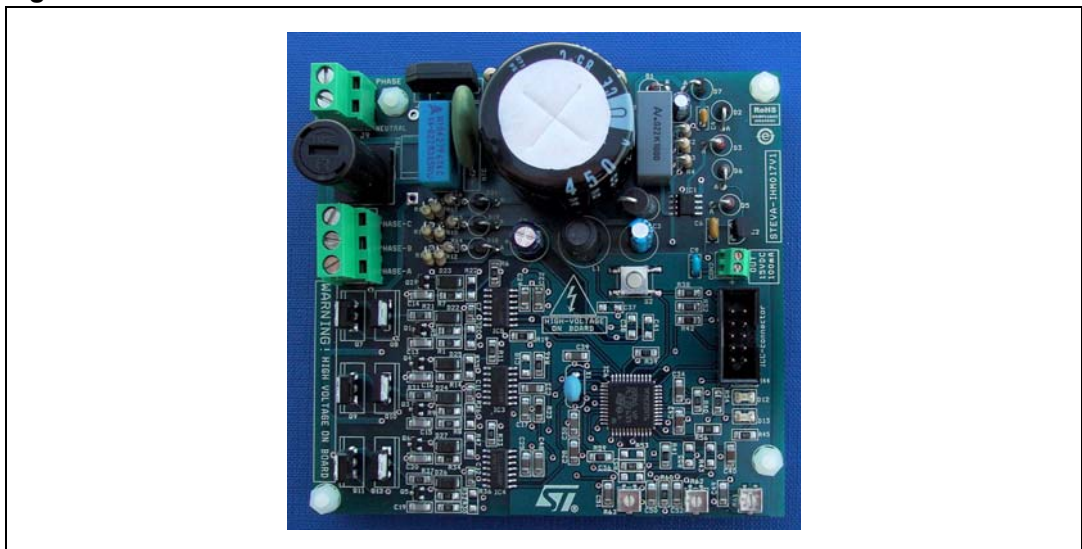
Introduction

The 100 W 3-phase inverter for the BLDC sensorless motor evaluation board (for brevity also referred with its order code STEVAL-IHM017V1) is a complete development platform for BLDC sensorless motor application with nominal power up to 100 W. It is based on a cost-effective, flexible and open design, including a three-phase inverter bridge based on the STD5NK52ZD-1 Power MOSFET in IPAK package and an ST7MC 8-bit microcontroller with 16 Kbyte internal Flash memory.

The system has been designed to drive a three-phase brushless motor with permanent magnet rotor exploiting trapezoidal sensorless control.

The STEVAL-IHM017V1 features complete hardware for developing motor control applications based on ST7MC peripherals including motor control peripheral (MTC). The STEVAL-IHM017V1 uses an in-circuit communication (ICC) standard interface to connect to the host PC via In-circuit debuggers/programmers such as the inDART-STX board from Softec. The board is designed to support 230 Vac of bus voltage up to 100 W of input power. It also includes a power supply stage with VIPer12A-E as the buck converter to generate voltage reference for the driver and the microcontroller.

Figure 1. STEVAL-IHM017V1 evaluation board



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1 Overview

1.1 Features

- Input voltage 220 - 230 Vac
- Maximum power 100 W
- Power MOSFET STD5NK52ZD-1 - 4.4 A 520 V included
- 15 V auxiliary power supply connector
- Programming and debug support via 10-pin ICC connector
- Three potentiometers for runtime settings
- Start/stop button
- Reset button

1.2 Applications

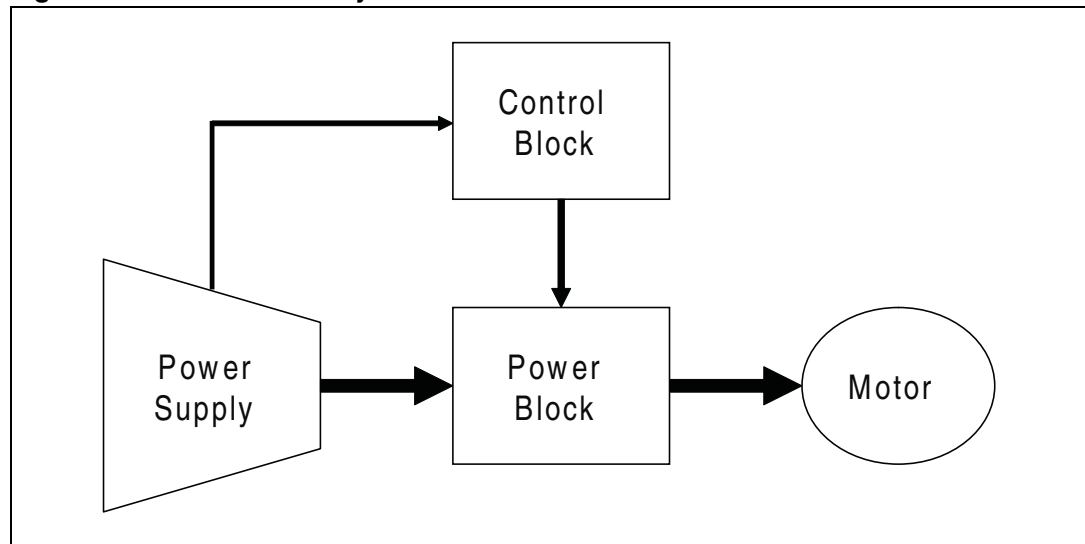
- Refrigerator compressors
- Dishwasher pumps

2 System architecture

A generic motor control system can be basically schematized as the arrangement of four main blocks (see [Figure 2](#)):

- A control block whose main tasks are to accept user command and motor drive configuration parameters and to provide digital signals to implement the proper motor driving strategy
- A power block that makes a power conversion from DC bus transferring it into the motor by means of a three-phase inverter topology
- The motor itself. The STEVAL-IHM017V1 board is able to drive a three-phase brushless motor with permanent magnet rotor exploiting trapezoidal sensorless control.
- The power supply block is able to accept 230 Vac input voltage and provide the proper levels to supply both the control block and power block devices.

Figure 2. Motor control system architecture



The system proposed by STEVAL-IHM017V1 includes all the above hardware blocks (apart the motor) plus a software GUI that allows configuring the motor drive. Moreover, an open source C code is available, derived from the ST7MC motor control libraries, allowing easy customization and extension of control algorithms. The core of the control block is constituted of an ST7MC MCU that provides the driving signals to the power block according to a driving strategy, the latter one closely related to the motor type and characteristics.

Driving signals are constituted of 3 complementary PWM signals (in the range of 0-5 V) for providing logic inputs for high/low side gate driver belonging to the power block. In the system proposed, three legs are present (3-phase inverter). The power block, based on the gate drivers L6386 and Power MOSFET (STD5NK52ZD-1), converts the control signals from ST7MC MCU to power signals for the three phase inverter in order to drive the motor. The board can be supplied by an AC power supply of 230Vac with a maximum input power of 100 W. Please refer to [Section 7: Board architecture on page 14](#) for more details on system architecture.

With the included Power MOSFET device STD5NK52ZD-1, the maximum rating of rectified voltage is 520 V and the maximum continuous current is 4.4 A at 25°C.

3 Safety and operating instructions

3.1 General

Warning: During assembly and operation, STEVAL-IHM017V1 evaluation board poses several inherent hazards, including bare wires, moving or rotating parts, and hot surfaces. There is danger of serious personal injury and damage to property, if the kit or its components are improperly used or installed incorrectly.

All operations involving transportation, installation and use, as well as maintenance are to be carried out by skilled technical personnel (national accident prevention rules must be observed). For the purposes of these basic safety instructions, "skilled technical personnel" are suitably qualified people who are familiar with the installation, use, and maintenance of power electronic systems.

3.2 Evaluation board intended use

The STEVAL-IHM017V1 evaluation board is a component designed for demonstration purposes only, and shall not be used for electrical installation or machinery. The technical data as well as information concerning the power supply conditions shall be taken from the documentation and strictly observed.

3.3 Evaluation board installation

The installation and cooling of the demonstration kit boards shall be in accordance with the specifications and the targeted application (see [Section 8: Motor control operations on page 19](#)).

The motor drive converters shall be protected against excessive strain. In particular, no components are to be bent, or isolating distances altered during the course of transportation or handling.

No contact shall be made with other electronic components and contacts.

The boards contain electrostatically sensitive components that are prone to damage through improper use. Electrical components must not be mechanically damaged or destroyed (to avoid potential health risks).

3.4 Electronic connections

Applicable national accident prevention rules must be followed when working on the main power supply with a motor drive. The electrical installation shall be completed in accordance with the appropriate requirements (e.g., cross-sectional areas of conductors, fusing, PE connections; for further information, see [Section 8: Motor control operations on page 19](#)).

3.5 Evaluation board operation

A system architecture which supplies power to the STEVAL-IHM017V1 evaluation board shall be equipped with additional control and protective devices in accordance with the applicable safety requirements (e.g., compliance with technical equipment and accident prevention rules).

Warning: Do not touch the board after disconnection from the voltage supply, as several parts and power terminals which contain possibly energized capacitors need to be allowed to discharge.

4 ST7FMC2S4T6 microcontroller functions

4.1 Main features

- TQFP44 package
- 16 Kbyte dual voltage Flash program memory with read-out protection capability
- 768 bytes RAM (256 stack bytes)
- Clock, reset and supply management with:
 - enhanced reset system
 - enhanced low voltage supervisor (LVD) for mains supply and auxiliary voltage detector (AVD) with interrupt capability
 - clock sources: crystal/ceramic resonator oscillators and bypass for external clock, clock security system
 - four power-saving modes: halt, active-halt, wait and slow
- Configurable window watchdog timer
- Nested interrupt controller with 14 interrupt vectors
- Two 16-bit timers
- One 8-bit auto-reload timer
- Serial peripheral interface (SPI) (not used in this evaluation board)
- Serial communication interface (LINSCI™) (not used in this evaluation board)
- Motor controller (MTC) peripheral with:
 - 6 high sink pulse width modulator (PWM) output channels
 - asynchronous emergency stop
 - analog inputs for rotor position detection
 - permanent magnet motor coprocessor including: multiplier, programmable filters, blanking windows and event counters
 - Operational amplifier and comparator for current limitation
- 10-bit analog-to-digital converter (ADC) with 11 inputs
- In-circuit communication interface (ICC, debug)

Table 1. ST7FMC2S4T6 functions

Function	I/O name	Description (depends on embedded software)
MTC	MCO0	PWM outputs high side phase A
	MCO1	PWM outputs low side phase A
	MCO2	PWM outputs high side phase B
	MCO3	PWM outputs low side phase B
	MCO4	PWM outputs high side phase C
	MCO5	PWM outputs low side phase C
	MCIA, MCIB, MCIC	Analog or digital input for position sensor or B.E.M.F. detection

Table 1. ST7FMC2S4T6 functions (continued)

Function	I/O name	Description (depends on embedded software)
MTC	MCV _{REF}	Not used in this evaluation board
	NMCES	Emergency stop
	OAP	Operational amplifier positive input
	OAN	Operational amplifier negative input
	OAZ	Operational amplifier output
	MCC _{REF}	Current limitation reference
	MCPWMV	PWM output V user for current reference
	MCZEM	Not used in this evaluation board
	MCDEM	Not used in this evaluation board
SPI	MISO	Master in/slave out data - not used in this evaluation board
	MOSI	Master out/slave in data - not used in this evaluation board
	SCK	Serial clock - not used in this evaluation board
LINSCI™	RDI	Received data input - not used in this evaluation board
	TDO	Transmit data output - not used in this evaluation board
10-bit ADC	AIN12	Trimmer R63 reading input
	AIN11	Trimmer R62 reading input
	AIN7	Trimmer P61 reading input
ICC	ICCCLK	Output serial clock
	ICCDATA	Input/output serial data
	ICCSEL/Vpp	Programming voltage input
Other I/O	PE2	Start/stop pushbutton
	PB7	LED management

5 STD5NK52ZD-1 characteristics

The STD5NK52ZD-1 is a n-channel Power MOSFET in the IPAK package (520 V - 1.22 Ω - 4.4 A) Zener-protected, SuperMESH™.

Figure 3. STD5NK52ZD-1, package and internal schematic diagram

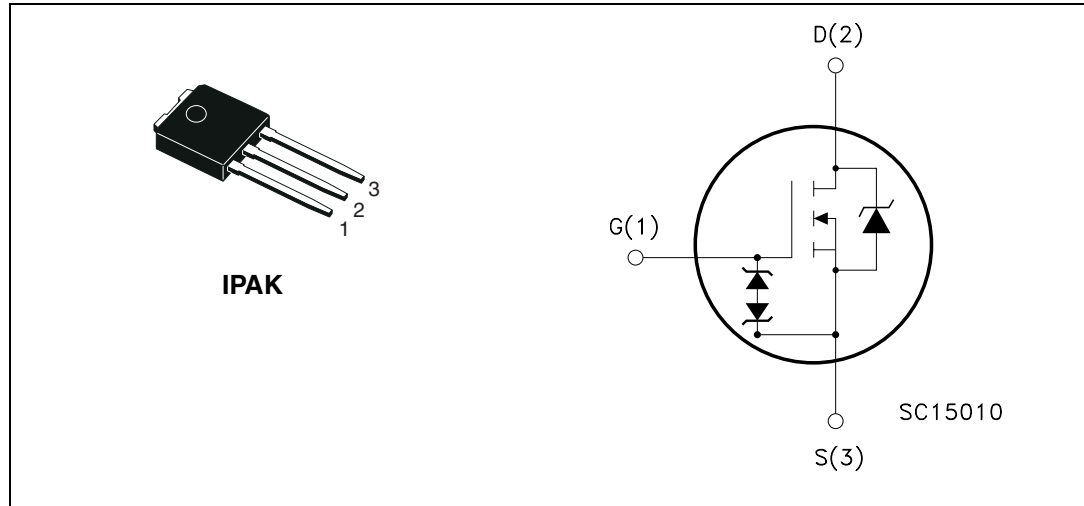


Table 2. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage ($V_{GS} = 0$)	520	V
V_{DGR}	Drain-gate voltage ($R_{GS} = 20\text{ k}\Omega$)	520	V
V_{GS}	Gate-source voltage	± 30	V
I_D	Drain current (continuous) at $T_C = 25^\circ\text{C}$	4.4	A
I_D	Drain current (continuous) at $T_C = 100^\circ\text{C}$	2.7	A
$I_{DM}^{(1)}$	Drain current (pulsed)	17.6	A
P_{TOT}	Total dissipation at $T_C = 25^\circ\text{C}$	70	W

1. Pulse width limited by safe operating area

Stresses above the limit shown in [Table 2](#) may cause permanent damage to the device.

6 Board electrical characteristics

Stresses above the limit shown in [Table 3](#) may cause permanent damage to the devices present inside the board. This is a stress rating only and functional operation of the device under these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability. 15 V bias current measurement can be useful to check the working status of the board. If measured value is considerably greater than typical value, it means that some damage has occurred in the board. Supply the control board using a 15 V power supply connected to CON2 observing the polarity.

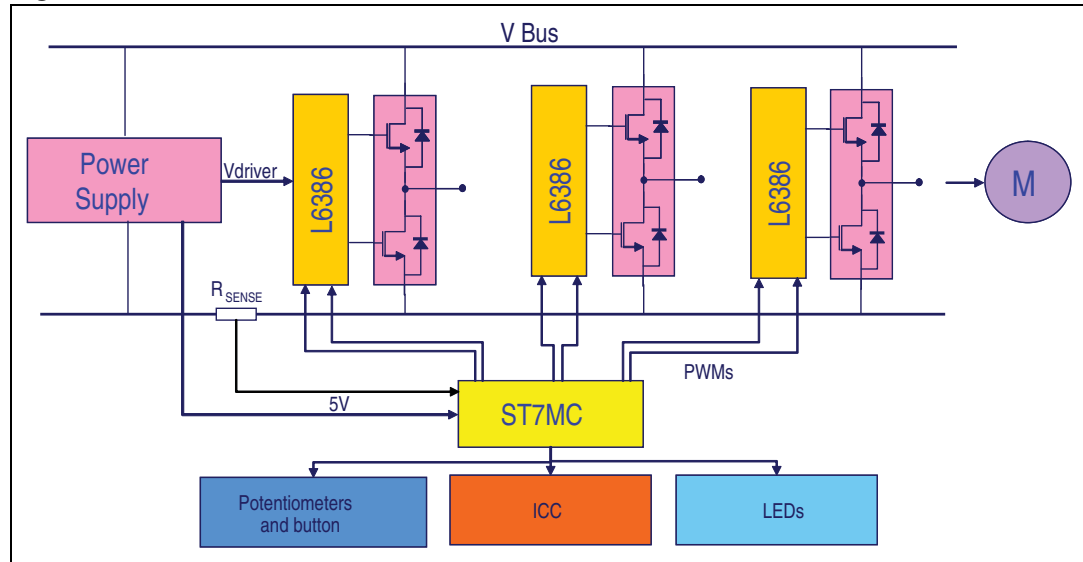
Table 3. Board electrical characteristics

Board parameters	STEVAL-IHM017V1		Unit
	Min	Max	
15 V auxiliary supply range – CON2	12	15	V
15 V bias current (typical)	23	23	mA
V_{BUS} – J9	30	270	Vac

7 Board architecture

The STEVAL-IHM017V1 can be schematized as in [Figure 4](#)

Figure 4. Board architecture



The heart of the evaluation board is the ST7MC microcontroller with a dedicated peripheral included to drive the three-phase brushless motor with permanent magnet rotor exploiting trapezoidal sensorless control. The board is provided with three potentiometers (R61, R62, R63) used for tuning, in real time, some parameters related to the drive. See [Section 8: Motor control operations on page 19](#).

Two LEDs (green/red) are used to get information about the status of the system. Their behavior is related to the drive. See [Section 8: Motor control operations on page 19](#).

In normal functionality it is expected that the board is supplied by VBUS connector J9 but an auxiliary supply connector CON2 is included on the board to feed the drivers and the microcontroller. This auxiliary supply can be useful for safety reasons, for example it should be used to program or debug the device without feeding the board with high voltage.

One communication system can be established with the microcontroller:

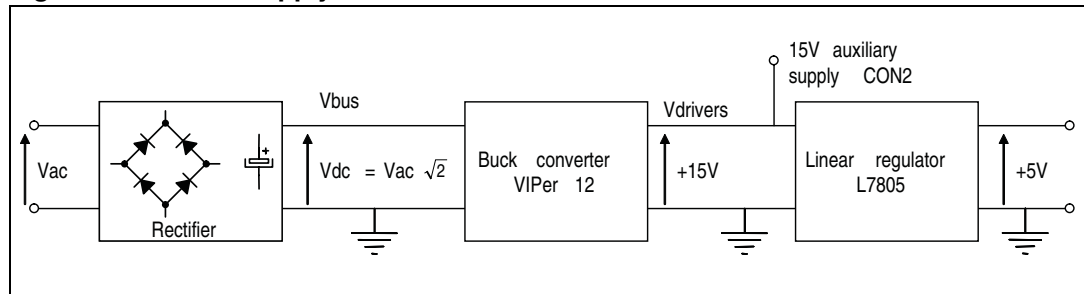
- ICC used for programming/debugging purposes

7.1 Power supply

The power supply is able to address a wide range of AC input voltage voltages from 30 Vac up to 270 Vac. The alternate current input is rectified by a diodes bridge and bulk capacitor to generate a direct current bus voltage approximately equal to $\sqrt{2}$ Vac minus the voltage drop on the bridge and ripple.

Then we have used a VIPer12A-E based buck converter to generate voltage reference for driver 15 V and a linear voltage regulator L7805 to generate the microcontroller voltage reference (see [Figure 5](#)).

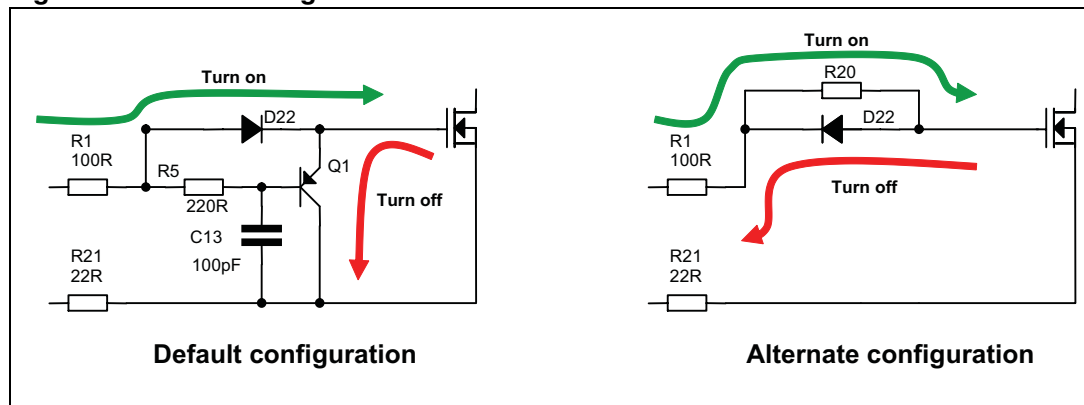
Figure 5. Power supply architecture



7.2 Power stage

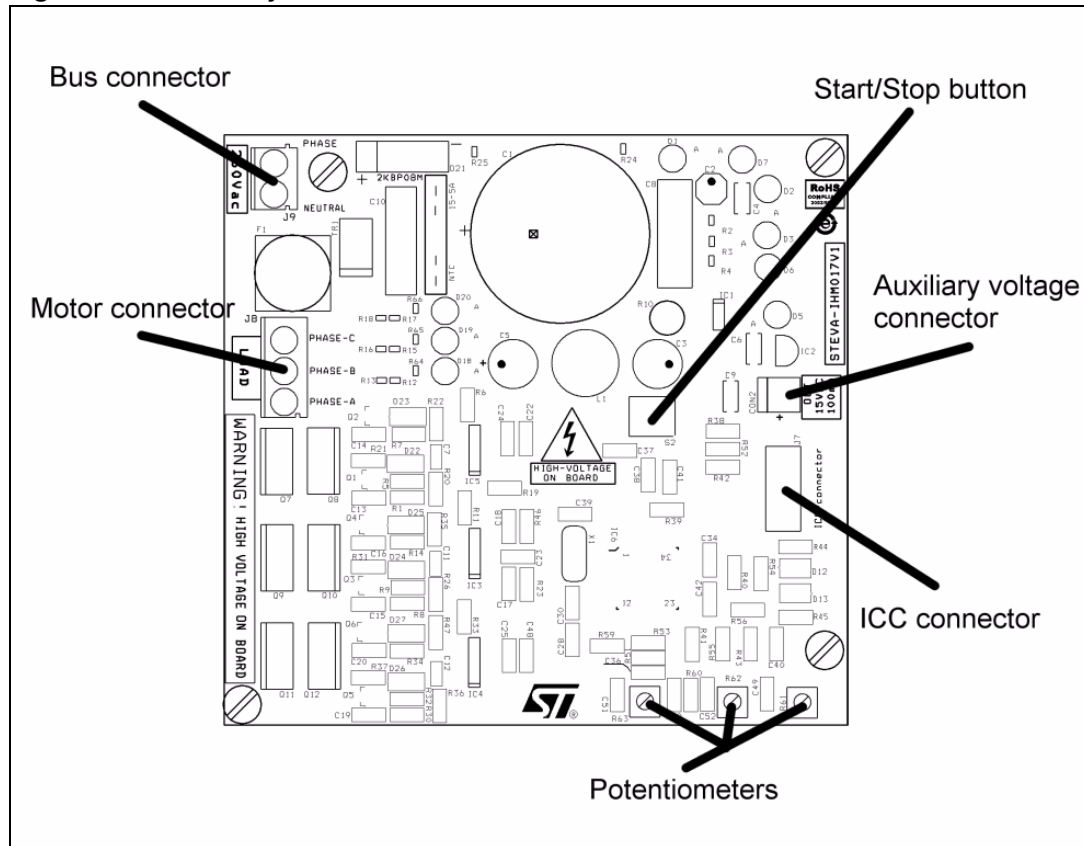
The power stage is based on six power MOSFETs in full 3-phase bridge configuration. In the board there are six STD5NK52ZD-1s in an IPAK package. Each device contains the freewheeling Zener diode. Three L6386 have been used to drive the Power MOSFETs gates and for hardware current protection. For each Power MOSFET in the 3-phase bridge the network shown in [Figure 6](#) (default configuration) has been used as the starting configuration.

Figure 6. Gate driving network



In this default configuration the gate of the Power MOSFET is turned on by means of R1 and D22 while the turnoff is performed very fast by means of the Q1 transistor. It is also possible to use the alternate configuration of the network (See [Figure 6](#)). To set this configuration transistor Q1, resistor R5 and C13 must be removed from each network (6). The direction of the diode D22 must be inverted and a resistor R20 must be mounted. In this alternate configuration the gate of the Power MOSFET is turned on by means of R1 and R20 while the turnoff is performed by means of R1 and D22.

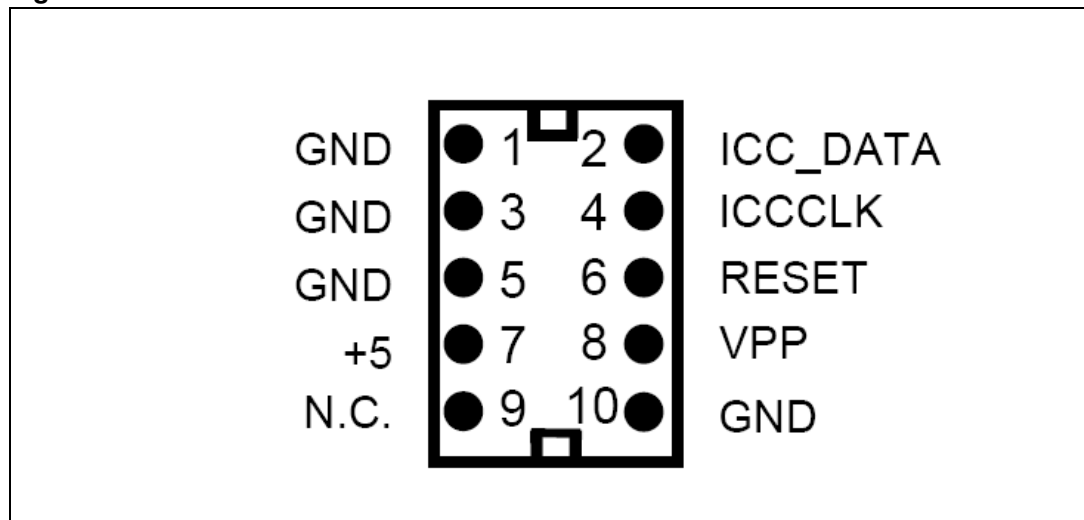
Figure 7. Board layout



7.3 ICC connector

The ICC connector (J7) is used to establish ICC communication for programming/debugging purposes. The pinout is shown in [Figure 8](#). This connector is compatible with Softec's inDART-STX board (not included in the package).

Figure 8. ICC connector



7.4 Board schematic

Figure 9. Board schematic - control block

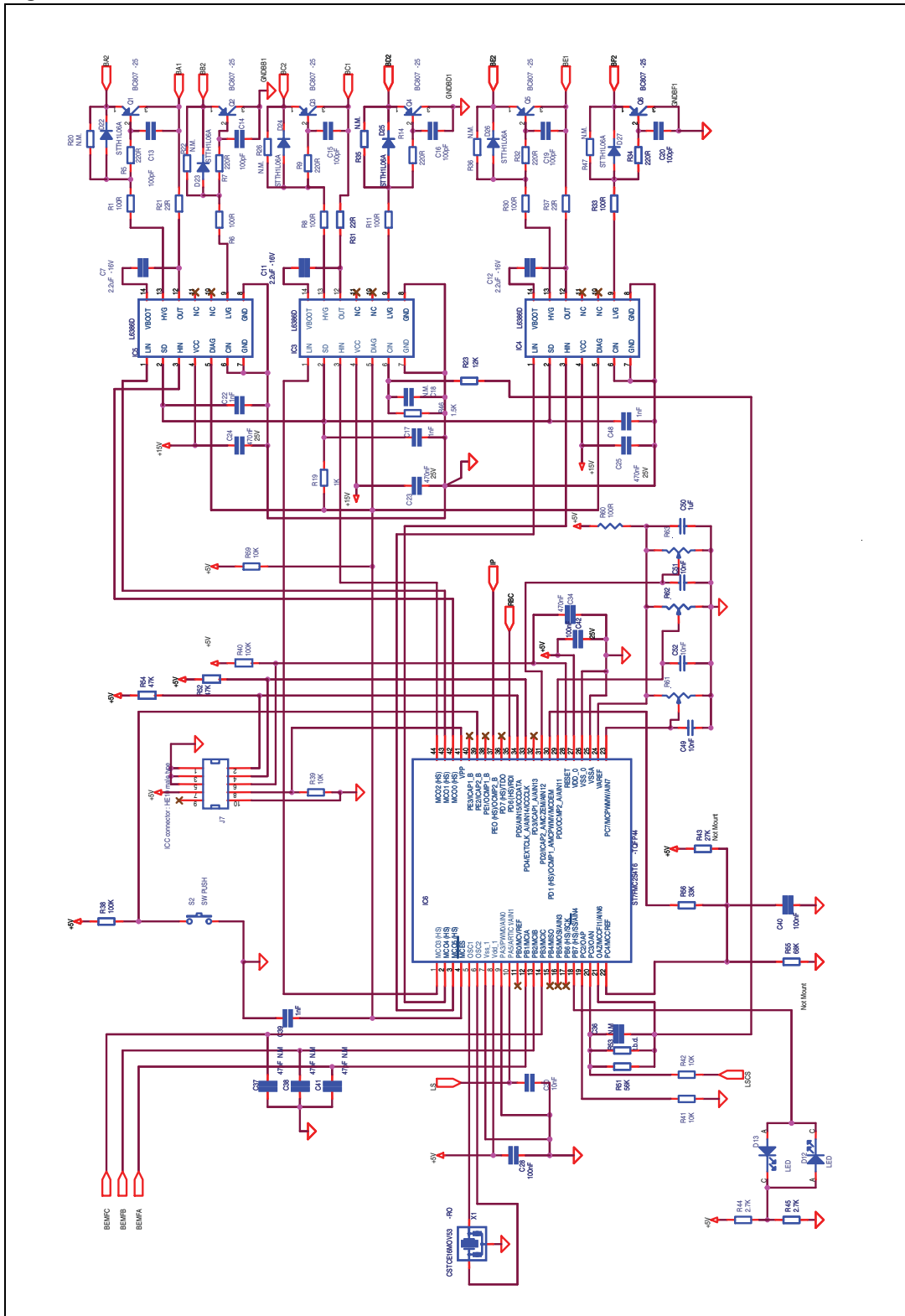
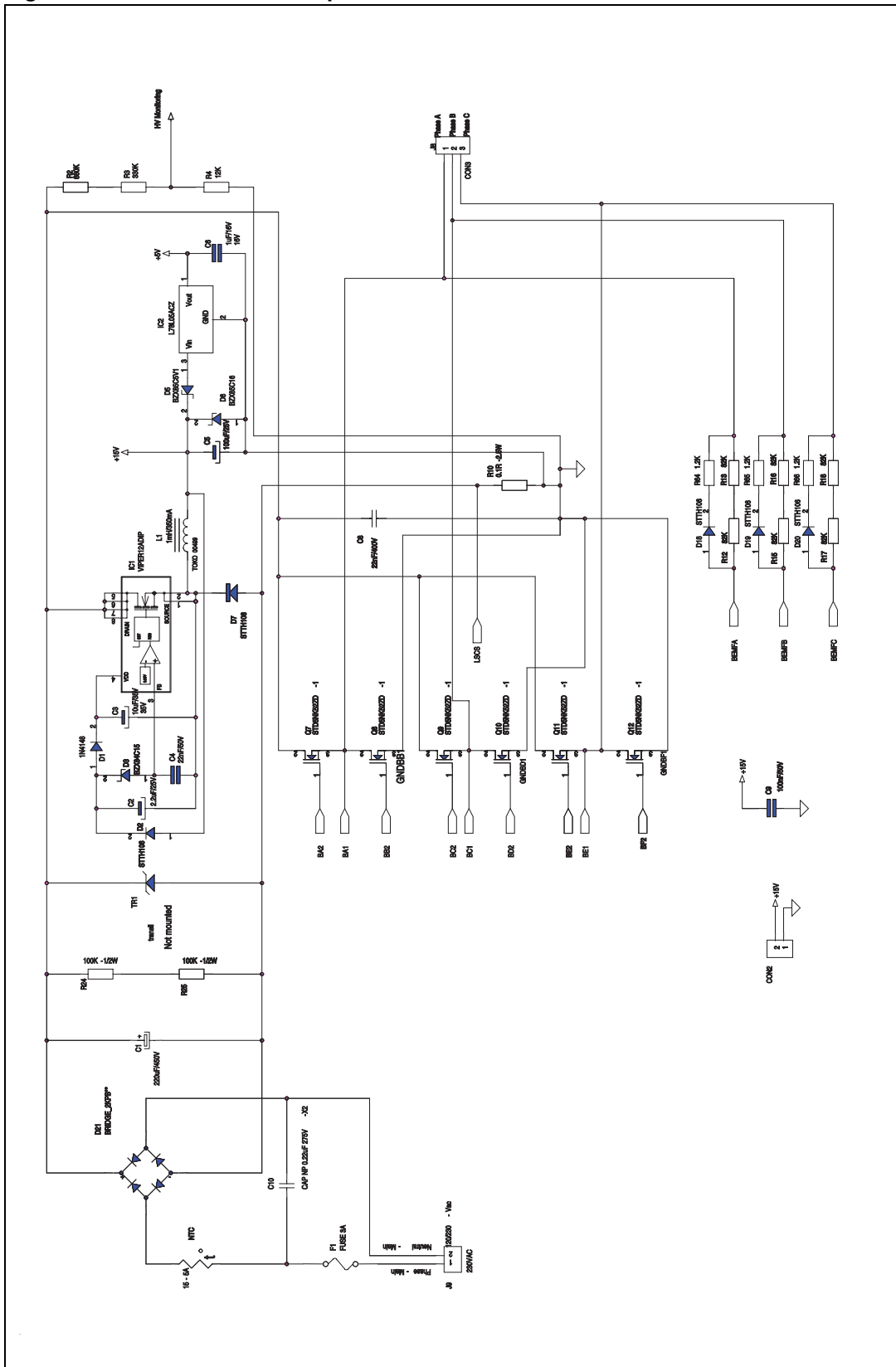


Figure 10. Board schematic - power block



8 Motor control operations

8.1 Environmental considerations

Warning: The STEVAL-IHM015V1 evaluation board must only be used in a power laboratory. The voltage used in the drive system presents a shock hazard.

The kit is not electrically isolated from the DC input. This topology is very common in motor drives. The microprocessor is grounded by the integrated ground of the DC bus. The microprocessor and associated circuitry are hot and MUST be isolated from user controls and communication interfaces.

Warning: Any measurement equipment must be isolated from the main power supply before powering up the motor drive. To use an oscilloscope with the kit, it is safer to isolate the DC supply AND the oscilloscope. This prevents a shock occurring as a result of touching any SINGLE point in the circuit, but does NOT prevent shocks when touching two or more points in the circuit.

An isolated AC power supply can be constructed using an isolation transformer and a variable transformer. A schematic of this AC power supply is in the application note, "AN438, TRIAC + microcontroller: safety precautions for development tools." (Although this application note was written for TRIAC, the isolation constraints still apply for switching semiconductor devices such as MOSFETs.)

Note: Isolating the application rather than the oscilloscope is highly recommended in any case.

8.2 Hardware requirements

To set up the STEVAL-IHM017V1 evaluation board system, the following items are required:

- The board: STEVAL-IHM017V1
- High-voltage insulated AC power supply up to 230 Vac
- Softec inDART-STX (not included in the package)
- Softec ICC isolation board (not included in the package)
- Two 10-pin flat cables (not included in the package)
- 3-phase brushless motor with permanent magnet rotor (not included in the package)
- Insulated oscilloscope (as needed)
- Insulated multimeter (as needed)

8.3 Software requirements

To customize, compile, and download the motor control firmware, the following software must be installed:

- "STEVAL-IHM017V1 - GUI" (included in the CD-ROM)
- STVD7 for inDART-STX V.3.11 (also called "ST7 Toolset" downloadable from Softec's website: www.softecmicro.com)
- Cosmic compiler - ST7 C compiler 16 Kbyte free version - 4.5c (downloadable from Cosmic's website: www.cosmic-software.com).

8.3.1 Installing the software

STEVAL-IHM017V1 - GUI installation

Insert the CD-ROM provided with the kit and execute Setup.exe.

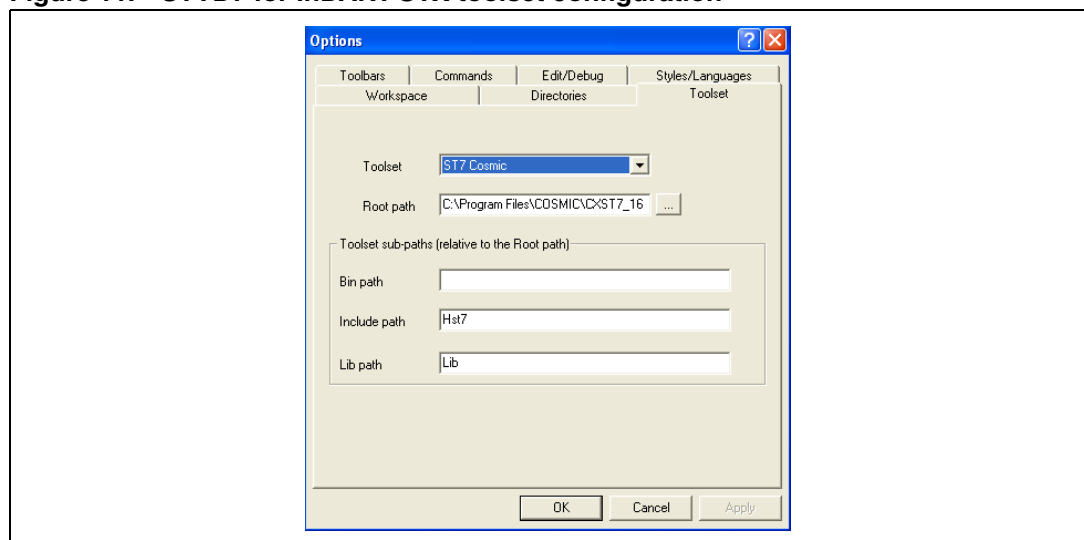
3rd party software installation

Follow the instructions of the related software to install and configure STVD7 for inDARTSTX and cosmic compiler.

Installation note

1. Install the Cosmic compiler first. Use the default installation folder: "C:\Program Files\COSMIC\CXST7_16Kbite". Registration is required before using the product. You can perform this procedure at any time by running the "Imreg16k.exe" file inside Cosmic's installation folder. Complete the form and click on the "Register by email" button. You will receive a license file "license.lic" that must be copied inside the installation folder under the "license" folder.
2. Then install STVD7 for inDART-STX. During the first run of the software after installation, a prompt for the configuration of the toolset should appear. The toolset can be configured at any time by opening "tools options" inside STVD7. To do this, click "toolset", and select the "toolset" menu tab, select "ST7Cosmic" and configure as in [Figure 11](#).

Figure 11. STVD7 for InDART-STX toolset configuration



8.4 Board setup

8.5 Firmware description

To address the driving of 3-phase brushless motor with permanent magnet rotor exploiting the sensorless trapezoidal control it is required to use the firmware named "BLDC_3PH_SL" (released for free). Together with the installation of "STEVAL-IHM017V1 - GUI" the BLDC_3PH_SL firmware source code is installed on the PC inside the installation folder under the "BLDC_3PH_SL" folder.

The following files are present inside the working folder:

- ".stw" file - STVD7 workspace file
- ".stp" file - STVD7 project file
- "source" folder - containing all .c and .h files required

Note: We suggest making a backup copy of the original working folder. The following procedure modifies the original content of the workspace folder without leaving the possibility to return to a previous step.

8.6 Configuring the firmware using GUI

Before "using" the firmware, it must be configured. The term "configure" indicates the act of selecting a specific driving strategy, such as open or closed loop, voltage or current mode and so on. The setting of customized parameters such as current limitation, motor settings, driving related parameters and so on is also indicated.

Configuring the firmware is performed by compiling a set of .h files inside the source folder and writing a series of values as fields of #define statements. To do this configuration, solid knowledge of the hardware and the architecture of the firmware is required. Otherwise, the configuration tool provided inside the CD-ROM called "STEVAL-IHM017V1 - GUI" can be used. This allows the user to choose and set all required parameters visually and the software automatically generates the ".h" files required (refer to the ".h" files that constitute the configurations related to the firmware in [Table 4](#)).

Table 4. Configuration ".h" files

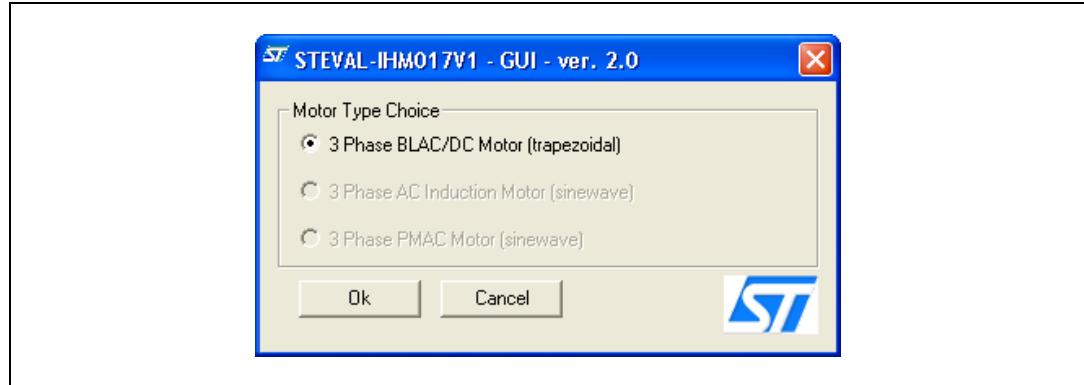
Firmware name	Configuration files
BLDC_3PH_SL	MTC_Settings_Sensorless.h
	spec_settings.h
	version.h

For a detailed description of the configuration files and how to manually customize the related parameters see AN1905.

8.7 Motor type selection

After "STEVAL-IHM017V1 - GUI" is started, the motor type choice dialog box appears (see [Figure 12](#)). In this window the user can choose the kind of motor. For this evaluation board only the 3-phase BLAC/DC motor (trapezoidal) is available.

Figure 12. Motor type choice window



Press the OK button.

8.8 "3-phase BLAC/DC (trapezoidal)" settings

Figure 13. "3-phase BLAC/DC (trapezoidal)" settings basic parameters window

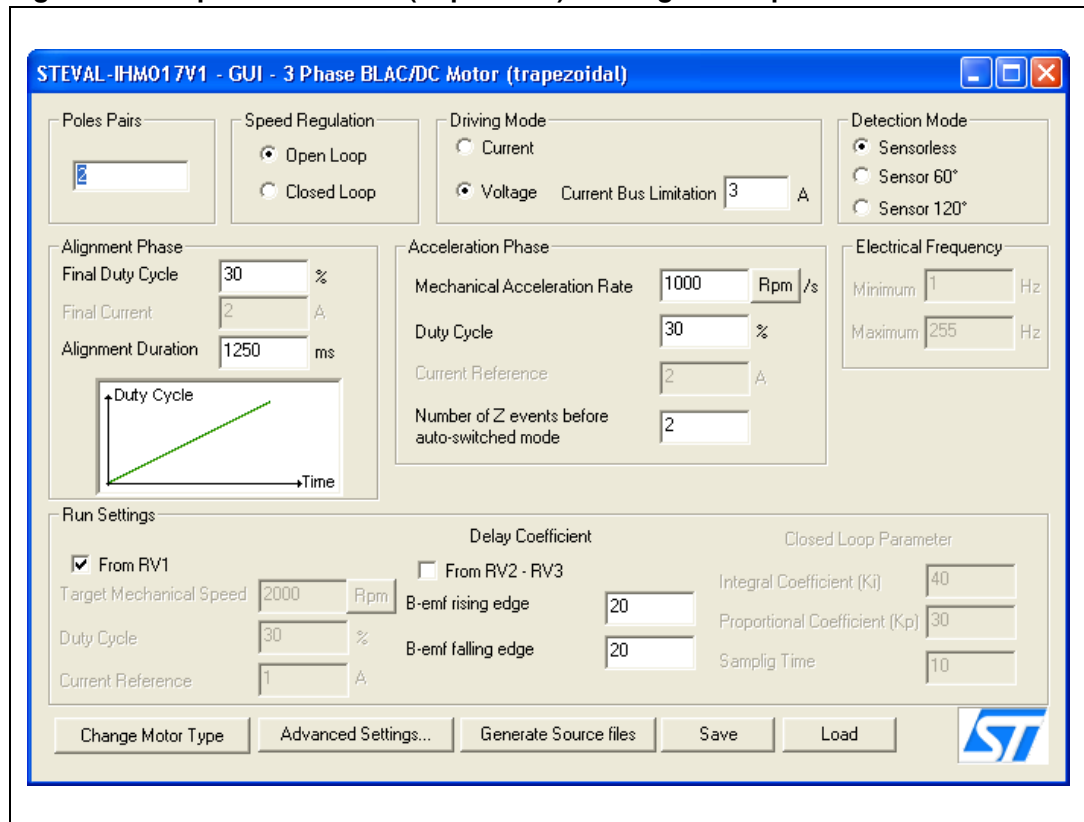


Table 5. "3-phase BLAC/DC (trapezoidal)" basic parameters

Parameter name	Description
Poles pairs	The number of pole (north/south) pairs in the motor
Speed regulation	The manner in which to run the motor, either open loop (without speed regulation) or closed loop (with speed regulation)
Driving mode	The motor driving mode, current mode or voltage mode
Current bus limitation	The software current limitation value (only in voltage mode), if the current flowing inside one (of three) phases of the motor reaches this value overcurrent is not generated but the pwm is managed to limit the current at this level.
Detection mode	The back EMF (BEMF) detection mode (rotor position), <i>only sensorless control is allowed in this evaluation board</i>
Alignment phase	
Final duty cycle	The percentage of final duty cycle applied at the end of alignment phase (only in voltage mode)
Final current	The value of current flowing inside the motor at the end of the "alignment phase" (only in current mode)
Alignment duration	The duration of the "alignment phase" in milliseconds (ms)
Acceleration phase	
Mechanical acceleration rate	The mechanical acceleration rate of the rotor during the ramp up in RPMs (or Hz) per second (alternate between RPM and Hz settings by clicking on the "RPM" button)
Duty cycle	The duty cycle percentage during the ramp up (only in voltage mode)
Current reference	The value of current flowing inside one (of three) phases of the motor at the end of the "acceleration phase" (only in current mode)
Number of Z events before auto-switched mode	The number of consecutive Z events that occur before the microcontroller runs the motor in autoswitched mode
Electrical frequency	
Minimum	The minimum target rotor frequency in closed loop, expressed in Hz
Maximum	The maximum target rotor frequency in closed loop, expressed in Hz
Run settings	
From RV1	When the "From RV1" checkbox is selected: duty cycle value is defined by the RV1 potentiometer (only for voltage mode), or current reference is defined by the RV1 potentiometer (only for current mode), or target speed is defined by the RV1 potentiometer (only for closed loop) if this box is unchecked, the above parameters are set by the user.
Duty cycle	The duty cycle percentage when the motor is run in "open loop" "voltage mode"

Table 5. "3-phase BLAC/DC (trapezoidal)" basic parameters (continued)

Parameter name	Description
Current reference	The value of current flowing inside one (of three) phases of the motor at run time in "open loop" "current mode"
Target speed	The target mechanical (rotor) Speed in RPMs (or Hz) if speed regulation is set to "closed loop" (alternate between RPM and Hz settings by clicking on the "RPM" button)
Delay coefficient from RV2-RV3	If the check box (Delay coefficient from RV2-RV3) is checked, then the Rising/Falling delay are set by R62 and R63. Otherwise if the check box is unchecked, these two parameters (Rising/Falling delay) can be set by the user in the following control boxes (B-emf rising/falling edge), in this case the two parameters are fixed and cannot be modified during the run time.
B-emf rising edge	The B-EMF Rising delay coefficient value (from 0 to 255)
B-emf falling edge	The B-EMF Falling delay coefficient value (from 0 to 255)
Closed loop parameter (only in closed loop)	
Integral coefficient (Ki)	The value of the Integral Coefficient (Ki) of the proportional integrative (PI) regulator
Proportional coefficient (Kp)	The value of the proportional coefficient (Kp) of the PI regulator
Sampling time	The regulation sampling time (in milliseconds)
Change motor type	the "change motor type" button enables the user to change the motor type (see Figure 13)
Advanced settings	the "advanced settings" button enables the user to set the advanced parameters (see Section 8.9: "3-phase BLAC/DC (trapezoidal)" advanced settings on page 24)
Generate source files	the "generate source files" button enables the user to generate the configuration ".h" files shown in Table 7 - configuration ".h" files. A "save" dialog window appears, where the user can select in which folder to create the file. User must choose the right "Source" directory in the firmware working folder (see Section 8.5: Firmware description on page 21).

8.9 "3-phase BLAC/DC (trapezoidal)" advanced settings

Clicking the "advanced settings" button (see [Figure 13](#)) opens the "advanced settings" dialog box (see [Figure 14](#)). This is where the advanced "3-phase BLAC/DC (trapezoidal)" motor type parameters are set.

Figure 14. "3-phase BLAC/DC (trapezoidal)" advanced parameters window

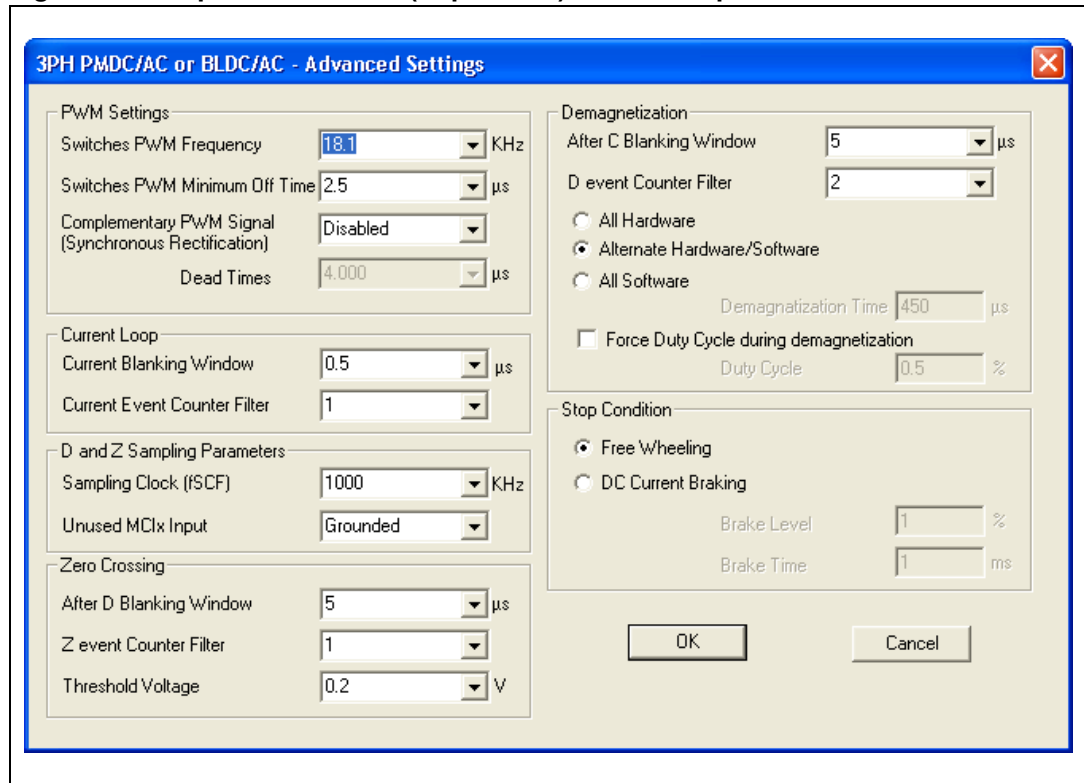


Table 6. "3-phase BLAC/DC (trapezoidal)" advanced parameters

Parameter name	Description
Switches PWM frequency	Pulse width modulation (PWM) frequency in kHz
Switches PWM minimum off time	PWM minimum off time in microseconds (μs) to detect the BEMF
Complementary PWM signal	If synchronous rectification it is enable or not
Deadtime	Value of deadtime in μs (only if Complementary PWM enabled)
Current loop	
Current blanking window	Time window filter in milliseconds to prevent erroneous sampling of the current after the PWM is turned ON
Current event counter filter	Defines the number of counter events required to validate a current limitation event
D and Z sampling parameters	
Sampling clock	Sets the frequency of the sampling clock for D and Z events in kHz
Unused MClx input	Defines in which state the unused MCl input is fixed, either "Grounded" or "Hi-Z"

Table 6. "3-phase BLAC/DC (trapezoidal)" advanced parameters (continued)

Parameter name	Description
Zero-crossing	
After D blanking window	Sets the blanking window after a D event in microseconds (μs)
Z event counter filter	Defines the number of counter events required to validate a Z event
Threshold voltage	Voltage set (in volts) for Z detection
Demagnetization	
After C blanking window	Sets the blanking window after a C event in microseconds (μs)
D event counter filter	Defines the number of counter events required to validate a D event
Demagnetization method	Three methods are available: "all hardware", "alternate hardware/software" or "all software"
Demagnetization time	Fixed demagnetization time in microseconds (μs) (only with demagnetization methods "all software")
Force duty cycle during demagnetization	Allows using a different value of duty cycle rather than the one in run time setting
Duty cycle	Value of duty cycle percentage forced during demagnetization
Stop condition	
Free wheeling	After stopping, the motor continues to spin freely
DC current braking	Active brake obtained injected dc current into the motor
Brake level	Value of duty cycle percentage of PWM brake signal
Brake time	Duration in milliseconds of the active brake

8.10 Changing the maximum current allowed by GUI

The maximum current allowed by GUI has been set to 4.4 A. This value may be changed by modifying the file "gui.ini" inside the folder where the " STEVAL-IHM017V1 - GUI" file is installed. Open the "gui.ini" file using the notepad and change the value of the following line:

- MAX_CURRENT = 4.4

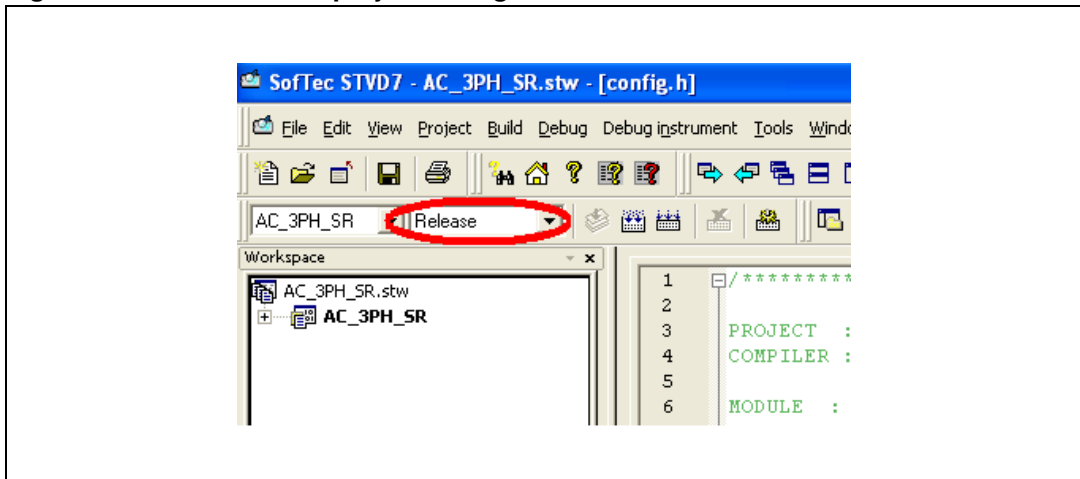
Replace the value 4.4 with the desired value of current limitation expressed in ampere. Remember that also the hardware current limitation must be changed accordingly, see [Section 8.10: Changing the maximum current allowed by GUI on page 26](#) to know how to modify this limitation.

8.11 Compiling the firmware

Once the configuration files have been produced (manually or using the GUI), the binary executable file (.s19) must be compiled and produced. To do this, the STVD7 for inDART-STX is used with the Cosmic compiler (see [Section 8.3: Software requirements on page 20](#))

1. Run the STDV7 for inDART-STX and choose "file > open workspace".
2. Select the workspace file under the "firmware working folder" depending on the motor type (see [Section 8.5: Firmware description on page 21](#)).
3. The default project in use is opened by the environment and is shown on the left side of the window below the opened ".stw" file.
4. Make sure that "Release" is set as the active project configuration (see [Figure 15](#)).

Figure 15. ST7VD active project configuration



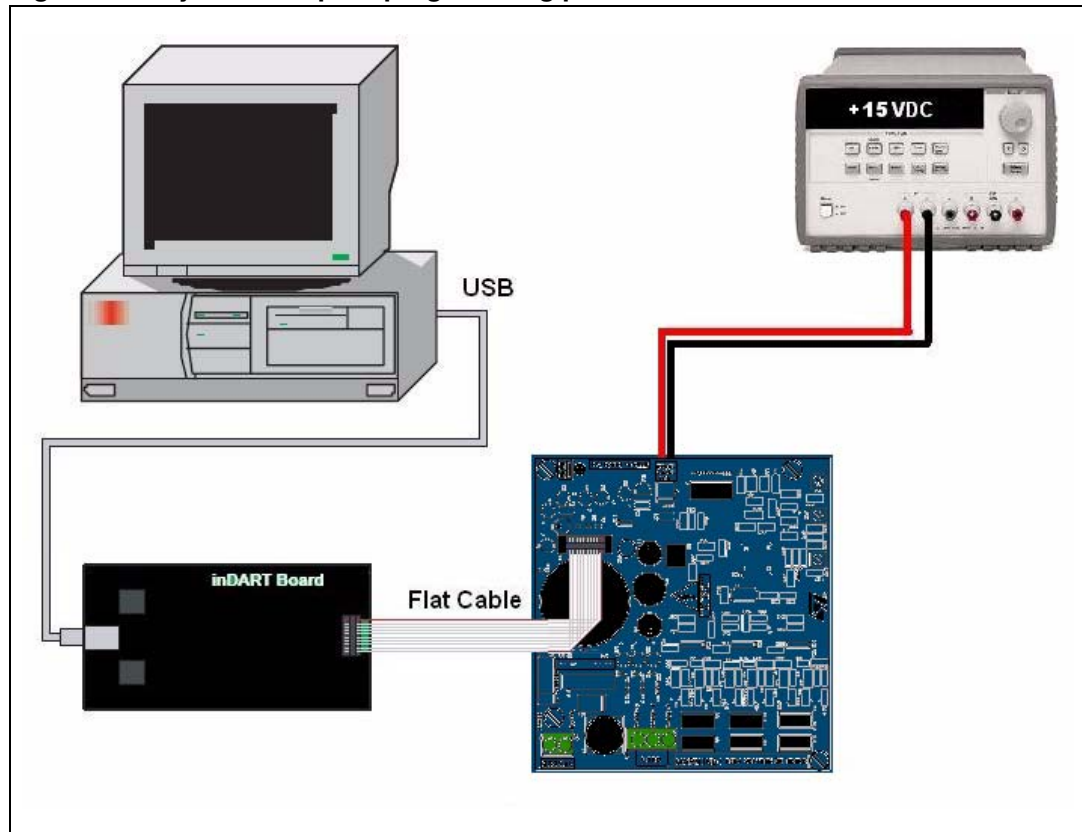
5. Use the "build" pull-down menu to display and select the "rebuild all" command. The project will be compiled and built, and an executable file "<firmware name>.s19" will be generated inside "release" folder under the workspace.

- Note:*
- 1 Make sure that the following string: "<firmware name>.elf - 0 error(s), 0 warning(s)" is displayed inside the output pane after the building of the executable.
 - 2 After the building of the executable, please ensure that the file "<firmware name>.s19" generated inside the "release" folder under the workspace has been created. To do this, show the properties and check the creation date.

8.12 Programming firmware

Before programming the firmware, the board must be supplied and connected to the PC using the inDART board. We suggest setting up the system as described in [Figure 16](#).

Figure 16. System setup for programming phase



1. Use the USB cable to connect the inDART-STX board to the PC. The green LED on the inDART-STX board turns on. The Windows® operating system automatically detects the new hardware and loads the appropriate USB and inDART-STX drivers.

Note: Windows 2000® and Windows XP® may issue a warning the first time the inDART-STX power board is connected to the PC. The USB driver used by inDART-STX is not digitally signed by Microsoft, however, the user may safely ignore the warning since every kind of compatibility and security test has been carried out by Softec Microsystems.

2. Connect the inDART board with the J7 connector using the 10-pin flat cable.
3. Supply the control board using a 15 V power supply connected to CON2 observing the polarity.

Once the ST7VD for inDART has been installed, the "datablaze programmer" utility that can be used to program the firmware using the inDART-STX is automatically installed.

4. Run the Softec datablaze programmer utility.
5. Click the "select device" button on the toolbar.
6. In the "select device" window, select "inDART-STX" in the "programmer hardware" box, and "ST7FMC2S4" as the device code, and press OK.

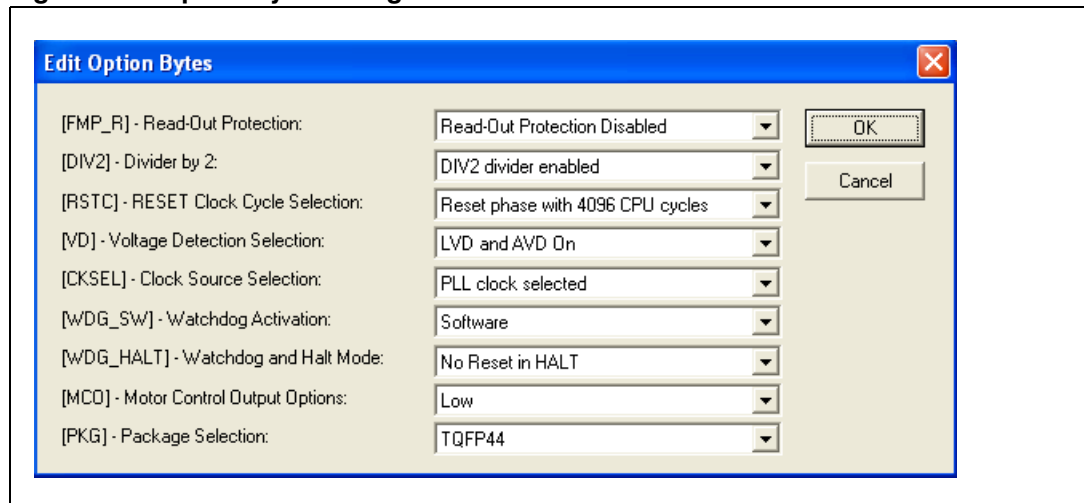
Note: If an error occurs, make sure that the inDART-STX board is connected to the PC. A green LED lights up if the board is connected.

7. Click on the file pull-down menu, select "load", then "code buffer".
8. In the "load file to code buffer" dialog box format menu, select "Motorola S-Rec" settings.
9. Click the button near "name" box and select the binary code (.S19) to download into the microcontroller, and press "OK" (to know which binary code to select, see [Section 8.11: Compiling the firmware on page 26](#)).

8.13 Setup option byte

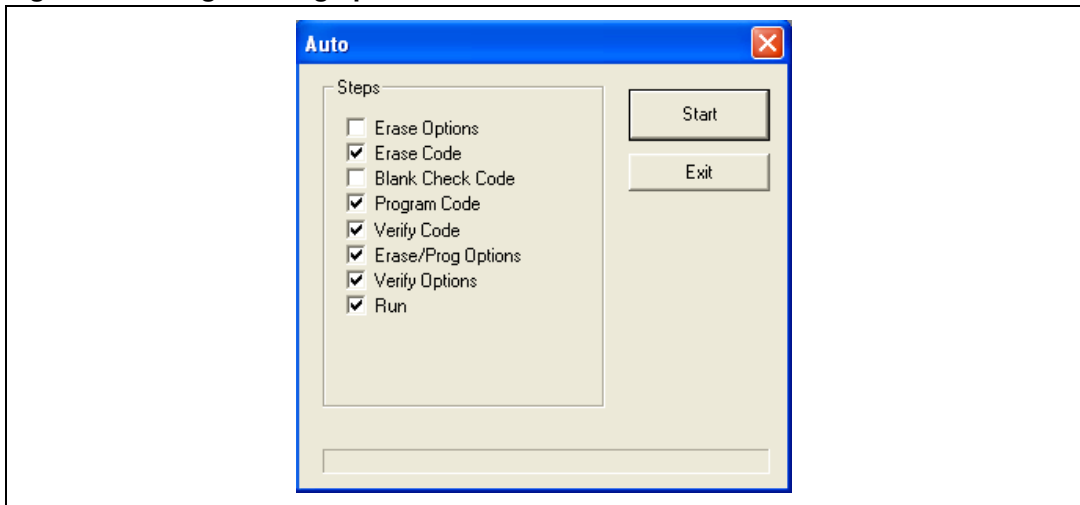
10. Press the "option byte" button in the toolbar and select the value as shown in the "option configuration" window (see [Figure 17](#)), and press "OK".

Figure 17. Option byte settings



11. Press the "auto" button in the toolbar and select the programming options as shown in [Figure 18](#).

Figure 18. Programming option auto window



12. Press "start" to program the device.

If an error window appears, make sure that the inDART-STX board is connected to the STEVAL IHM017.01 board and that the board is well supplied.

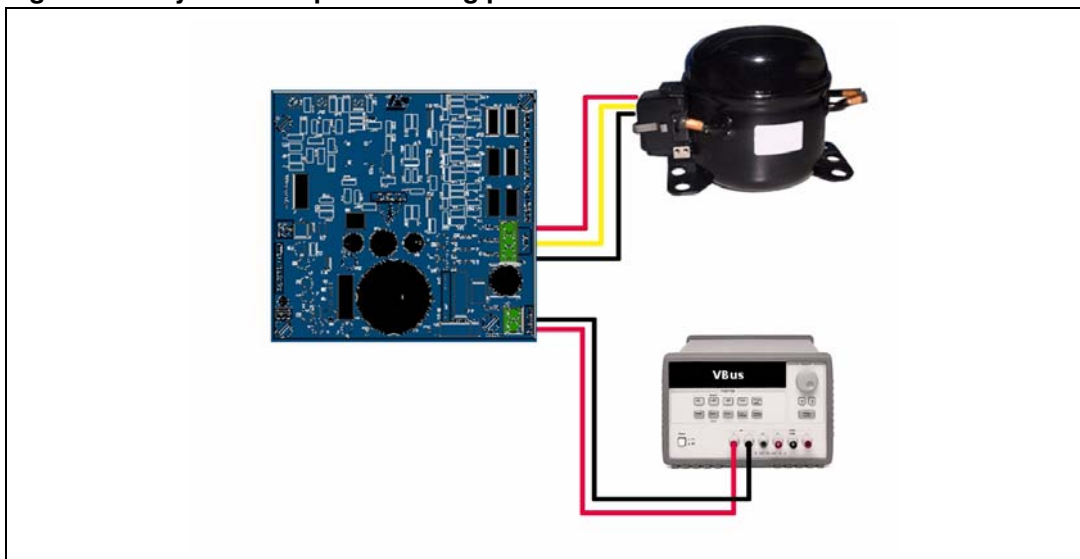
13. After programming check LED behavior to verify that the firmware has been correctly downloaded.

8.14 Board connection

After the board has been programmed, the system can be configured as shown in [Figure 19](#). This configuration is called a "running configuration". Remove the ICC flat cable from the board if present.

1. Connect the insulated AC power supply to the J9 connector of STEVAL-IHM017V1.
2. Connect the phases of the motor to the J8 connector of the board.

Figure 19. System setup for running phase



At this point the system is ready to run. If the hardware current limitation set by default for this board (8 A) has to be modified, go to next paragraph, otherwise it is possible to skip to paragraph [Section 8.16: Driving the BLDC motor \(trapezoidal - sensorless\) on page 32](#).

8.15 Changing the maximum current level allowed

An overcurrent protection mechanism is included inside the board that protects the system, disabling all the power switches if current that flows inside the motor is greater than a certain threshold. If this occurs, the red LED starts blinking. This mechanism is called "hardware current protection".

This threshold value is fixed by the hardware to 8 A.

To change this threshold to I_{MAX} (expressed in A), resistor R51 (expressed in k Ω) must be modified according to equation 1.

Equation 1:

$$R_{51} = \frac{450}{I_{MAX}} K\Omega$$

For example if the desired threshold is 2.2 A it is required to use $R_{51}=200k\Omega$

Note: A place holder named R53 in parallel to R51 is also included that can be useful if the calculated value is not a standard value resistor. In this case it is possible to get better accuracy using two standard value resistors in parallel to get the calculated value.

For a lower value of current threshold, in order to avoid noise on current feedback, the shunt resistor R10 may be reduced, in which case the formula that should be used is equation 2:

Equation 2:

$$R_{51} = \frac{45}{I_{MAX} \cdot R_{10}} K\Omega$$

If R51 and/or R10 are changed, the "gui.ini" file must be modified. This file is stored in the same folder as the "STEVAl-IHM017.01 - GUI" file.

First calculate the Amplification factor using equation 3:

Equation 3:

$$A = \frac{R_{51}}{10K\Omega}$$

Open the "gui.ini" file using the notepad and change the value of the following line:

```
MAX_CURRENT = 4.4
```

```
...
```

```
AMP_SENS = 5.6
```

```
R_SENS = 0.1
```

Replace the value 4.4 with I_{MAX} expressed in amps, the value 5.6 with the A value calculated by equation 3, and 0.1 with the value of R10.

Remember to close and re-open "LVST7MC - GUI" to activate this modification and follow the instructions in [Section 8.6: Configuring the firmware using GUI on page 21](#).

8.16 Driving the BLDC motor (trapezoidal - sensorless)

Let's start the demonstration driving the brushless permanent magnet motor sensorless, so at this point please check that the board has been set up for sensorless driving (See [Section 8.8: "3-phase BLAC/DC \(trapezoidal\)" settings on page 22](#)).

To drive the motor also in closed loop mode, it is not required that the motor include any position or speed sensor.

8.17 LED behavior after power-on

Turn on the power supply. For this demonstration the power supply output voltage should be set to 230 Vac and the current limitation of the power supply should be set to 2 A. After power-on the control board LED behavior should be the following:

- LED D12 blinks signaling that the firmware has started to run.
- After a while LED D13 stays on to indicate "idle state".

8.18 Potentiometers functionality

If enabled during the configuration the three potentiometers R61, R62, R63 can be used to set run time parameters. See [Table 7](#) to understand their functionality.

Table 7. Potentiometer functionality based on open/closed loop driving strategy

Voltage mode		
	Open loop	Closed loop
R61	Sets the duty cycle percentage from 0% to the maximum duty cycle allowed.	Sets the target rotor frequency value from minimum value to maximum value configured (see Section 8.8: "3-phase BLAC/DC (trapezoidal)" settings on page 22)
R62	Sets the value of rising delay coefficient from 0 to 255	
R63	Sets the value of falling delay coefficient from 0 to 255	
Current mode		
	Open loop	Closed loop
R61	Sets the current reference value from 0 A to maximum current allowed.	Sets the target rotor frequency value from minimum value to maximum value configured (see Section 8.8: "3-phase BLAC/DC (trapezoidal)" settings on page 22)
R62	Sets the value of rising delay coefficient from 0 to 255	
R63	Sets the value of rising delay coefficient from 0 to 255	

If during the configuration using GUI, the "from RV1" control has been unchecked, then the value of the duty cycle (or the value of current reference) is not set by R61 but has a fixed value. If during the configuration using GUI, the "from RV2 - RV3" control has been unchecked, then the value of the rising delay coefficient and the value of the falling delay coefficient are not set by P2 and P3 but have fixed values.

Note: The value of rising and falling delay are expressed in 255th of last measured step time. So 0 means no delay between zero-crossing and commutation, while 255 means that the delay between zero-crossing and commutation is equal to last step time.

The maximum duty cycle allowed in voltage mode depends on the value of PWM frequency and the value of PWM min off time set by the GUI. The maximum current allowed by GUI has been set to 4.4 A. (see [Section 8.10: Changing the maximum current allowed by GUI on page 26](#)).

In "idle state" (D13 led is ON), push the start/stop button to start the motor. The D13 LED is turned OFF and D12 LED is turned ON to indicate that the firmware has been switched to "run state".

In "run state" (D12 led is ON), push again the start/stop button to stop the motor. The D12 LED is turned OFF and D13 LED is turned ON to indicate that the firmware has been switched to "idle state".

9 Bill of material

Table 8. Bill of materials

Item	Reference	Part	Footprint
1	CON2	CON2	TRH-pitch 2.54mm
2	C1	220 μ F/450 V	TRH-pitch 10mm
3	C2	2.2 μ F/50 V	TRH-pitch 2.54mm
4	C3	10 μ F/50 V	TRH-pitch 3.5mm
5	C4	22 nF/50 V	TRH-pitch 2.54mm
6	C5	100 μ F/25 V	TRH-pitch 3.5mm
7	C6	1 μ F/50 V	TRH-pitch 2.54mm
8	C7,C11,C12	2.2 μ F/16 V	SMD-0805
9	C8	22 nF/400 V	TRH-pitch 15.24mm
10	C9	100 nF/50 V	TRH-pitch 2.54mm
11	C10	0.22 μ F/275 V/x2	TRH-pitch 15.24mm
12	C13,C14,C15,C16,C19,C20	100 pF	SMD-1206
13	C17,C22,C39,C48	1 nF	SMD-1206
14	C18	N.M.	Not assy
15	C23,C24,C25,C34	470 nF	SMD-1206
16	C28,C40,C42	100 nF	SMD-1206
17	C30,C49,C51,C52	10 nF	SMD-1206
18	C36	N.M	Not assy
19	C37,C38,C41	N.M	Not assy
20	C50	1 μ F	SMD-1206
21	D1	1N4148	TRH-Verticale
22	D2,D18,D19,D20	STTH1L06	TRH-Verticale
23	D3	BZX84C15	TRH-Verticale
24	D5	BZX85C5V1	TRH-Verticale
25	D6	BZX85C16	TRH-Verticale
26	D7	STTH108	TRH-Verticale
27	D12,D13	LED	SMD-1206
28	D21	BRIDGE_2KPB**	TRH
29	D22,D23,D24,D25,D26,D27	STTH1L06A	SMD-1406
30	J8	Morsetto a vite 3 poli.	pitch-5mm
31	J9	Morsetto a vite 2 poli.	pitch-5mm

Table 8. Bill of materials (continued)

Item	Reference	Part	Footprint
32	F1	FUSE 3A-verticalecon fusibile	TRH
33	IC1	VIPer12AS-E	
34	IC2	L78L05ACZ	
35	IC3,IC4,IC5	L6386D	
36	IC6	ST7FMC2S4T6	
37	J7	ICC connector : HE10 male type	TRH-
38	L1	1 mH/350 mA	TRH-PICTH 5.0mm
39	Q1,Q2,Q3,Q4,Q5,Q6	BC807-25	SOT23
40	Q7,Q8,Q9,Q10,Q11,Q12	STD5NK52ZD-1	
41	R1,R6,R8,R11,R30,R33,R60	100 Ω	SMD-1206
42	R2	680 Ω	TRH
43	R3	330 Ω	TRH
44	R4	12 Ω	TRH
45	R23	12 Ω	SMD-1206
46	R5,R7,R9,R14,R32,R34	220 Ω	SMD-1206
47	R10	0.1 Ω -3 W	TRH
48	R12,R13,R15,R16,R17,R18	82 Ω	TRH
49	R19	1 Ω	SMD-1206
50	R20,R22,R35,R47,R26,R36	N.M.	Not assy
51	R21,R31,R37	22 Ω	SMD-1206
52	R24,R25	100 k Ω -1/2W	TRH
53	R38,R40	100 Ω	SMD-1206
54	R39,R41,R42,R59	10 Ω	SMD-1206
55	R43	N.M.	NOT ASSY
56	R44,R45	2.7 Ω	SMD-1206
57	R46	1.5 Ω	SMD-1206
58	R51	56 Ω	SMD-1206
59	R52,R54	47 Ω	SMD-1206
60	R53	N.M.	Not assy
61	R55	N.M.	Not assy
62	R56	33 Ω	SMD-1206
63	R64,R65,R66	1.2 Ω	TRH

Table 8. Bill of materials (continued)

Item	Reference	Part	Footprint
64	R61,R62,R63	50K code RS 100-1199 12,64 x 10 e distrelec 50k cod 740218 0.82x 10	
65	S2	SW PUSH	SMD
66	TR1	N.M.	
67	X1	CSTCE16MOV53-RO	TRH-3pin
68	15-5A	NTC	TRH
69	Nylon spacer	10 mm	Any

10 References

This user manual provides information about using the STEVAL-IHM017V1 and its hardware features. For additional information about supporting software and tools, please refer to:

1. ST7MC datasheet: complete information about microcontroller features and peripherals.
2. ST7MC motor control related application notes: complete information about motor control libraries developed for the ST7MC microcontroller.
3. STD5NK52ZD-1 datasheet: complete information about the Power MOSFET devices included.
4. Website and motor control forum: <http://www.st.com/mcu/>

11 Revision history

Table 9. Document revision history

Date	Revision	Changes
07-Apr-2008	1	Initial release

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