2 kW 3-phase motor control STEVAL-IHM028V2 evaluation board featuring the IGBT intelligent power module STGIPS20C60
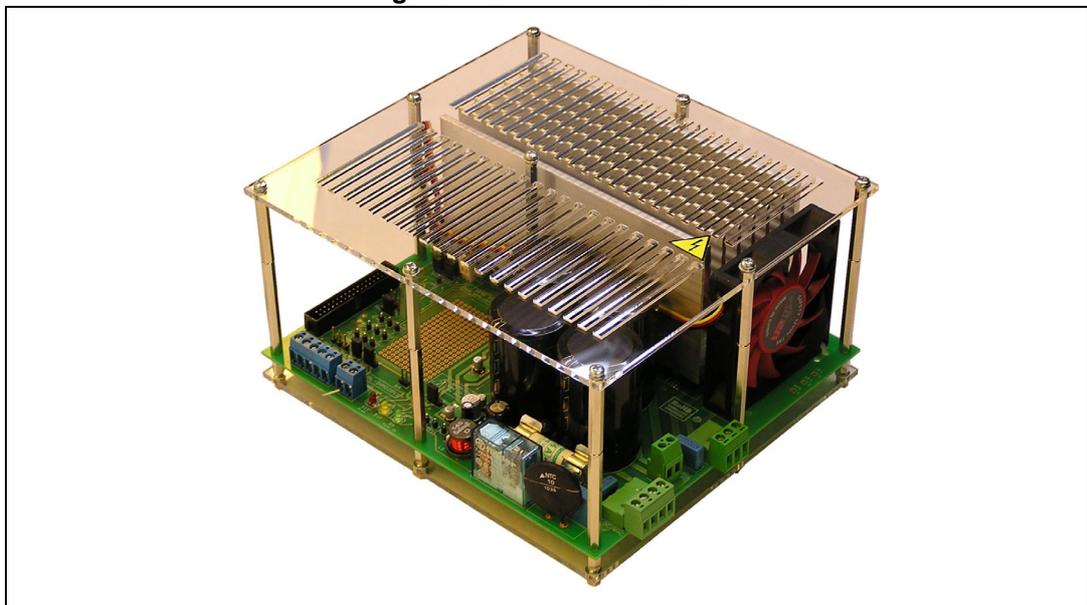
Introduction

This document describes the 2 kW 3-phase motor control evaluation board featuring the IGBT intelligent power module STGIPS20C60. The evaluation board is an AC-DC inverter that generates a 3-phase waveform for driving 3-phase motors such as induction motors or permanent magnet synchronous motors (PMSM) up to maximal 2000 W with or without sensors.

The main device presented in this user manual is a universal, fully evaluated and populated design consisting of a 3-phase inverter bridge based on the 600 V IGBT power module in the SDIP 25L package mounted on a heatsink. The IGBT power module integrates all power IGBT switches with freewheeling diodes together with high voltage gate drivers. Thanks to this integrated module, the system has been specifically designed to achieve power inversion in a reliable and compact design. Such integration saves PCB space occupation and assembly costs, together with high reliability due to the design simplicity.

The board is designed to be compatible with single-phase mains, supplying from 90 VAC to 285 VAC or from 125 VDC up to 400 VDC for the DC voltage.

This document is associated with the release of the STEVAL-IHM028V2 evaluation board (see *Figure 1*).

Figure 1. STEVAL-IHM028V2

Contents

1 System introduction

1.1 Main characteristics

The information listed below shows the converter specification data and the main parameters set for the STEVAL-IHM028V2 evaluation board.

- Minimum input voltage 125 VDC or 90 VAC
- Maximum input voltage 400 VDC or 285 VAC
- With applied input voltage doubler - the range from 65 VAC to 145 VAC
- Maximum output power for applied motor up to 2000 W
- Regenerative brake control feature
- Input inrush limitation with bypassing relay
- +15 V auxiliary power supply based on a buck converter with VIPer™26
- Using IGBT intelligent power module STGIPS20C60 in SDIP 25L molded package
- Fully populated board conception with test points and safety isolated plastic cover
- Motor control connector for interface with STM3210B-EVAL board, STM8/128-EVAL board, and other ST motor control dedicated kits
- Tachometer input
- Hall/encoder inputs
- Overheating protection
- Active fan cooling of heatsink with automatic temperature switch
- Possibility to connect MB843 BLDC daughterboard for sensor-less six-step control
- PCB type and size:
    - Material of PCB - FR-4
    - Double-sided layout
    - Copper thickness: ~60 μm

Total dimensions of evaluation board: 195 mm x 175 mm.

1.2 Target application

- Power fans for HVAC application
- Power tools
- Industrial drives
- High-power industry pumps
- Professional washing machines.

1.3 Safety and operating instructions

1.3.1 General terms

Warning: During assembly, testing, and normal operation, the evaluation board poses several inherent hazards, including bare wires, moving or rotating parts, and hot surfaces. There is a danger of serious personal injury and damage to property if the kit or components are improperly used or installed incorrectly. The kit is not electrically isolated from the AC/DC input. The evaluation board is directly linked to the mains voltage. No insulation is ensured between the accessible parts and the high voltage. All measuring equipment must be isolated from the mains before powering the board. When using an oscilloscope with the demo, it must be isolated from the AC line. This prevents shock from occurring as a result of touching any single point in the circuit, but does NOT prevent shock when touching two or more points in the circuit. Do not touch the evaluation board after disconnection from the voltage supply; several parts and power terminals, which contain energized capacitors, must be allowed to discharge.

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 purpose of these basic safety instructions, "skilled technical personnel" are considered as suitably qualified people who are familiar with the installation, use, and maintenance of power electronic systems.

1.3.2 Eevaluation board intended use

The STEVAL-IHM028V2 evaluation board is designed for evaluation purposes only and must not be used in final applications. The technical data, as well as information concerning the power supply conditions, must only be taken from the relevant documentation and must be strictly observed.

1.3.3 Evaluation board installation

The installation and cooling of the evaluation board must be done in accordance with the specifications and the targeted application.evaluation

• The motor drive converters are 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 must 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.

1.3.4 Electrical connections

Applicable national accident prevention rules must be followed when working on the main power supply. The electrical installation must be carried out in accordance with the appropriate requirements.

A system architecture which supplies power to the evaluation board must 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).

2 Board description

2.1 System architecture

A generic motor control system can be basically schematized as the arrangement of four main blocks (see *Figure 2*).

- **Control block** - its main task is to accept user commands and motor drive configuration parameters. It provides all digital signals to implement the proper motor driving strategy. The STM3210B-EVAL evaluation board, based on the STM32 microcontroller can be used as the control block, thanks to the motor control connector equipped on the STEVAL-IHM028V2.

- **Power block** - it is based on 3-phase inverter topology. The heart of the power block is the STGIPS20C60 integrated intelligent power module which contains all the necessary active components. Please refer to the STGIPS20C60 datasheet for more information.

- **Motor** - the STEVAL-IHM028V2 evaluation board is able to properly drive any PMSM, but the FOC itself is mostly conceived for sinusoidal shaped back-EMF. The evaluation board is also convenient for driving any 3-phase asynchronous motor.

- **Power supply block** - able to work from 90 VAC to 285 VAC or from 125 VDC to 400 VDC. The power block is based on a buck converter with a VIPer26 controller. Please refer to *Section 3* to properly set the jumpers according to the required application.

Figure 2. Motor control system architecture
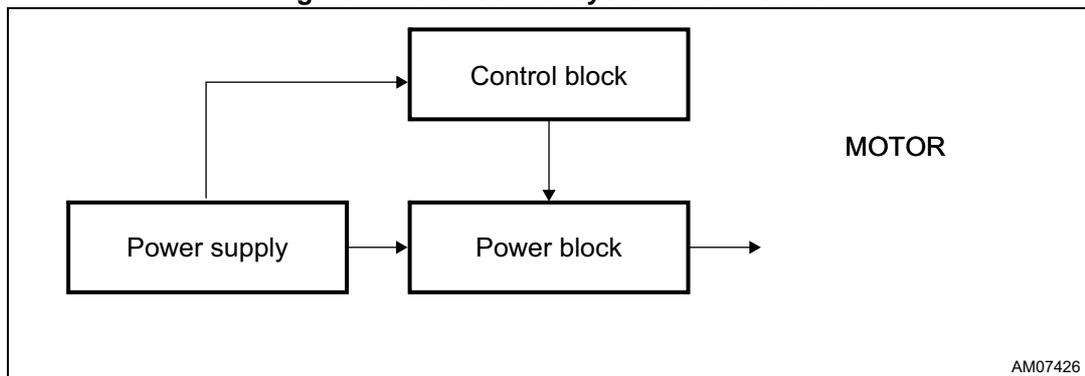
Of the above motor control system architecture, the STEVAL-IHM028V2 includes the power supply and the power block hardware blocks.

2.2 Board schematic

Figure 3. STEVAL- IHM028V2 schematic - part 1

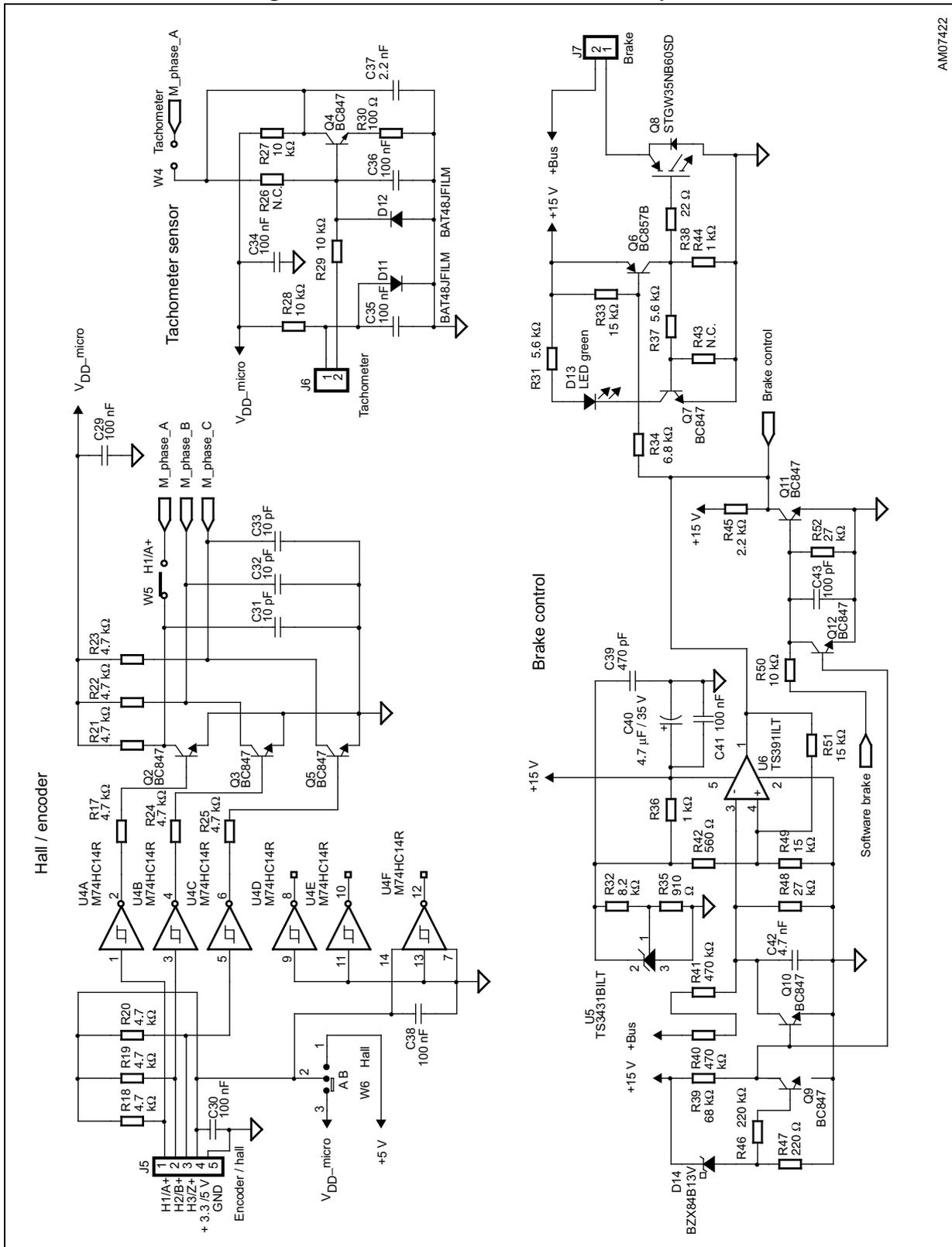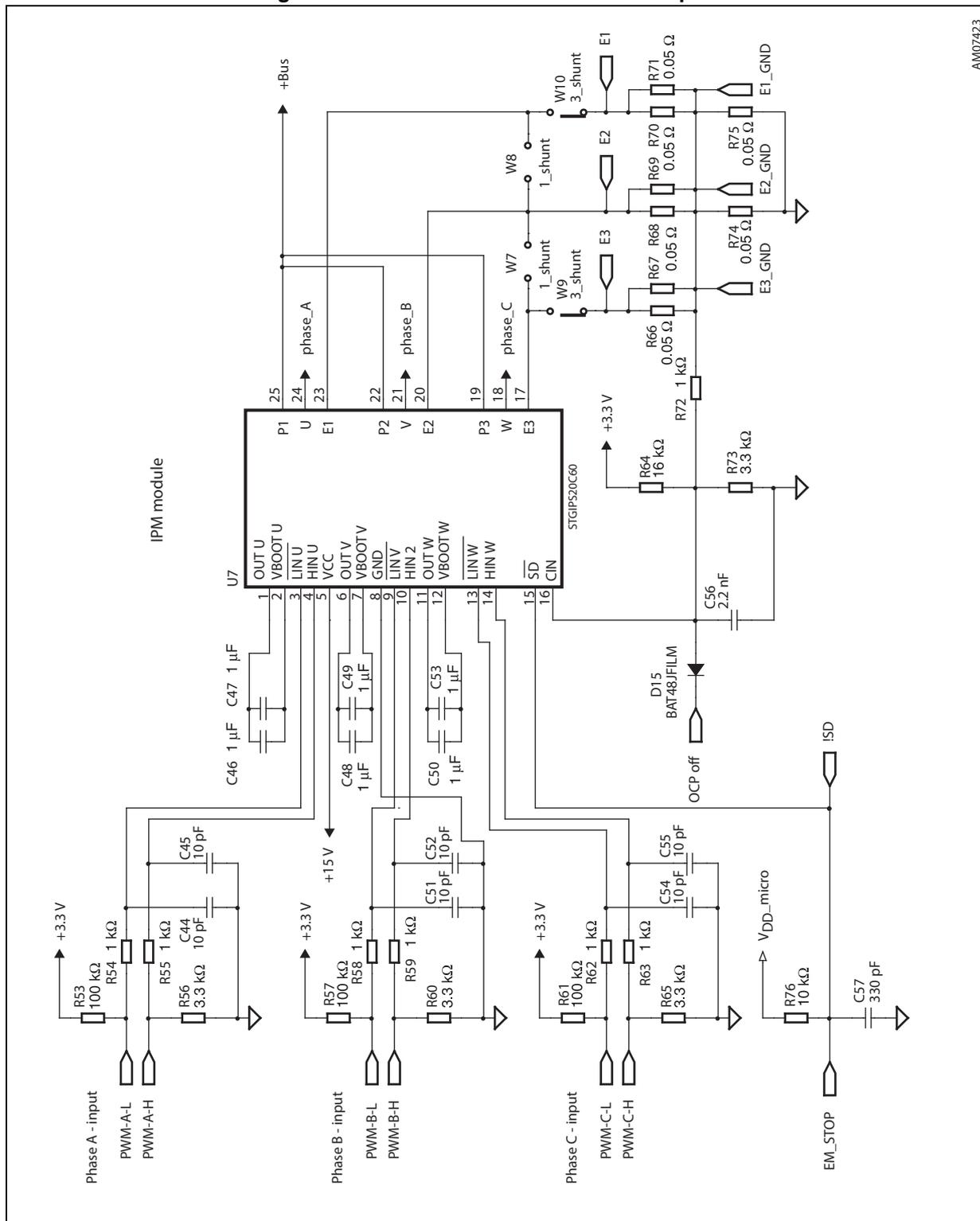**Figure 4. STEVAL- IHM028V2 schematic - part 2**
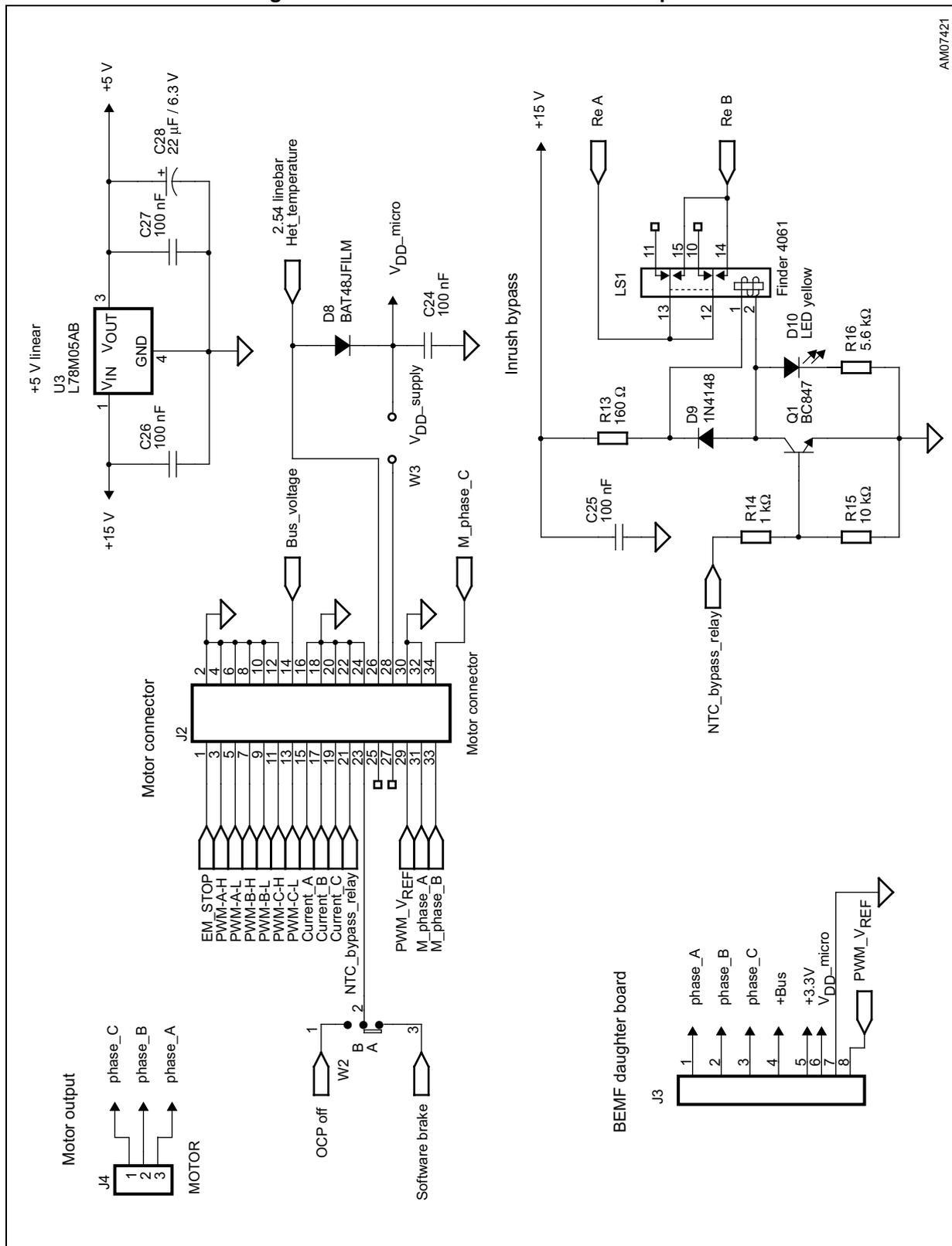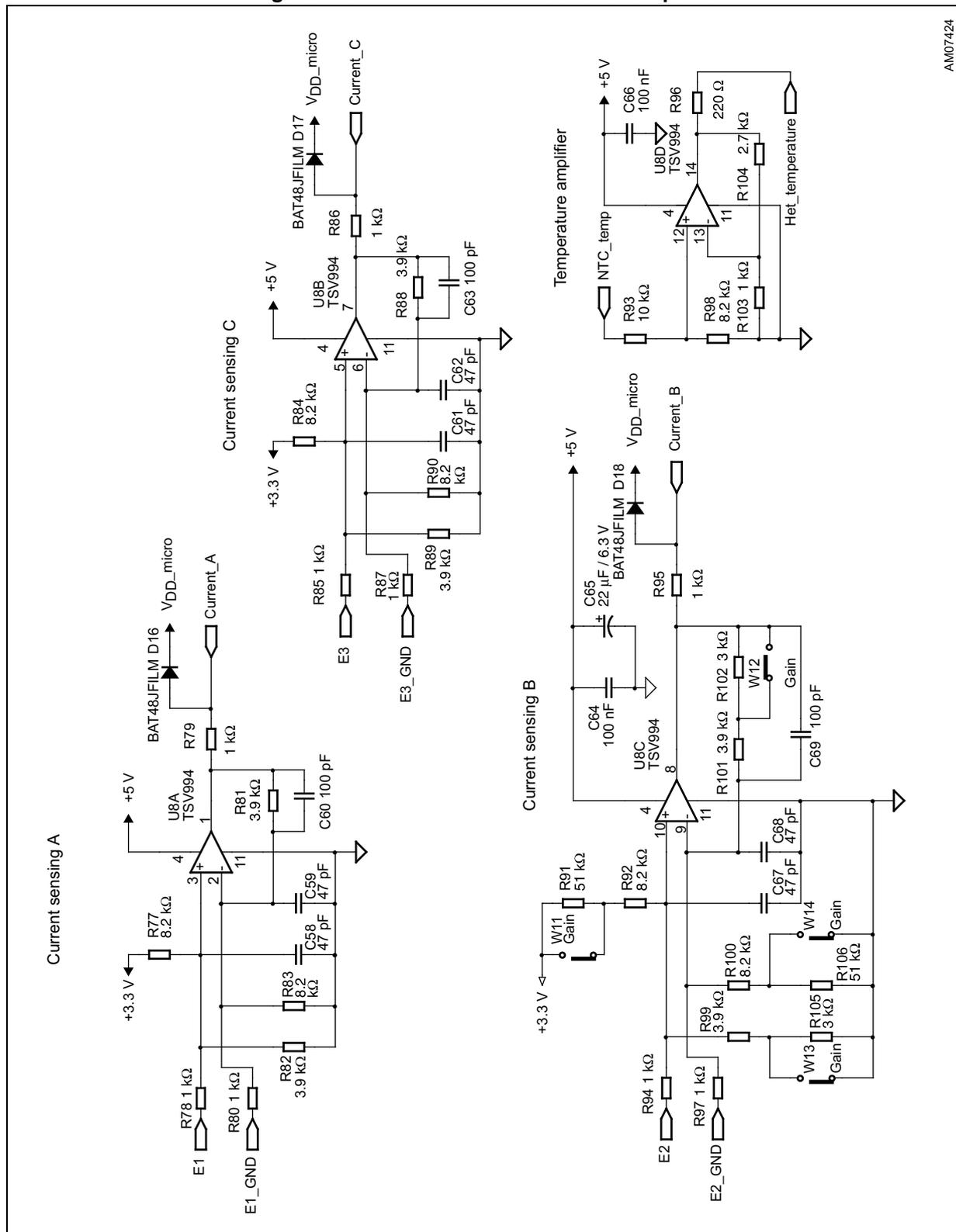
Figure 5. STEVAL- IHM028V2 schematic - part 3

Figure 6. STEVAL- IHM028V2 schematic - part 4

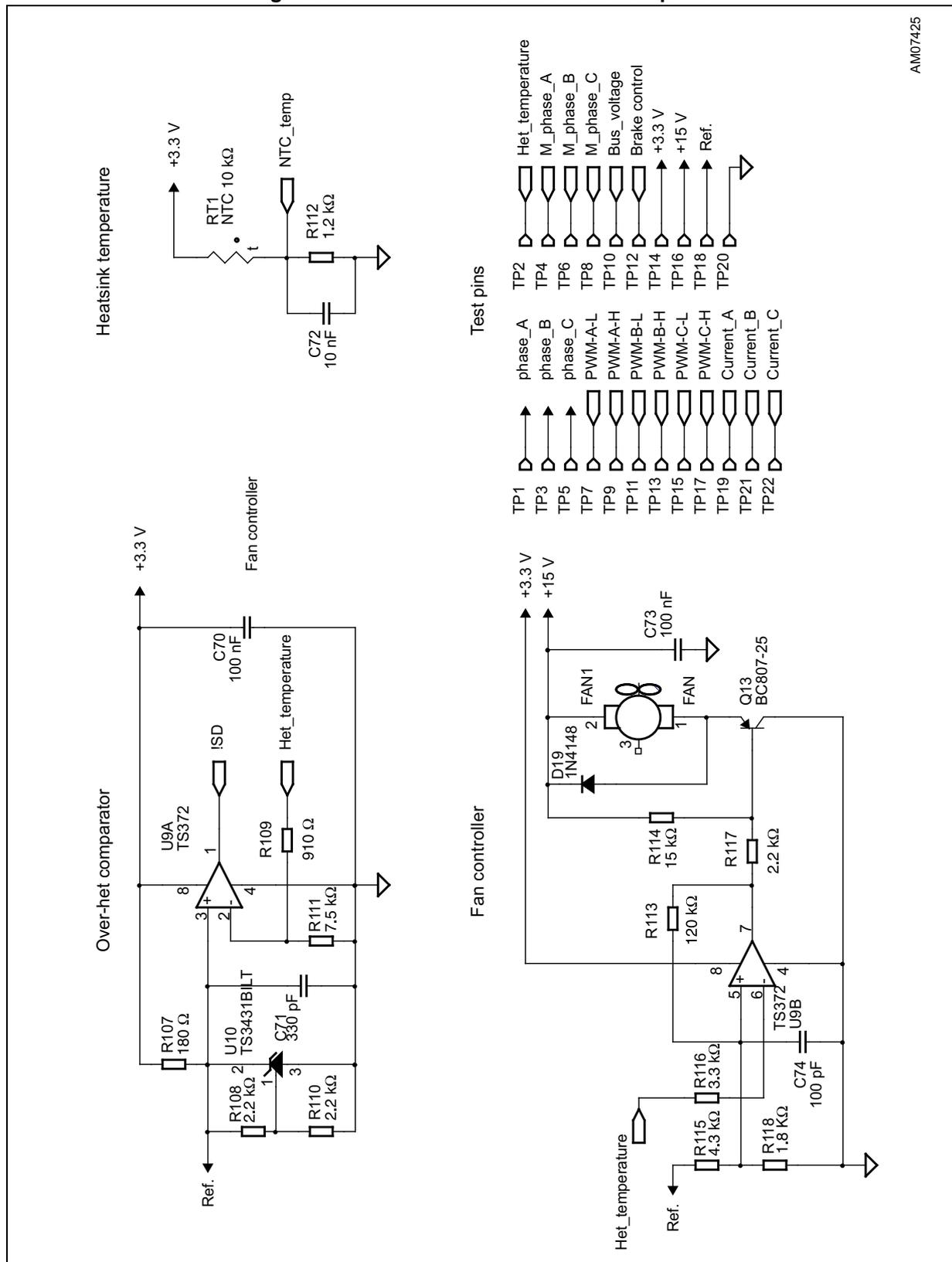## Figure 7. STEVAL- IHM028V2 schematic - part 5

Figure 8. STEVAL- IHM028V2 schematic - part 6

2.3 Circuit description

2.3.1 Power supply

The power supply for the STEVAL-IHM028V2 evaluation board is implemented as
a wide range converter. The range of the input voltage is from 90 VAC or 125 VDC up to 285
VAC or 400 VDC. This range allows the evaluation board to be used in direct connection
with various single phases as well as the PFC input stage.

If the input AC voltage does not surpass 145 VAC, it is possible to apply the input voltage
doubler, this is done by shorting the W15 jumper. This configuration almost doubles the
input AC voltage to a standard level and allows to evaluate the motor control application with
a low level of input AC voltage.

The auxiliary power supply for all active components on the evaluation board is
implemented as a buck converter based on U2 VIPer26L which works with a fixed frequency
of 60 kHz. The output voltage of the converter is +15 VDC. Voltage is fed into the intelligent
power module (IPM) as supply voltage, as well as into linear regulators LF33ABDT and
L78M05AB. Linear regulators provide +3.3 VDC and +5 VDC for supplying operational
amplifiers and further related parts placed on the evaluation board. The selection of supply
voltage for hardware peripherals placed on the board is done with jumper W1. In the "A"
position the supply voltage selected is +3.3 V and in the "B" position it is +5 V. Thanks to
jumper W3, it is possible to supply the connected MCU driving board with related supply
voltage. Maximal consumptive current of the MCU unit must not surpass 50 mA. Please
refer to the VIPer26LD datasheet for more information.

Information regarding the value of the supply bus voltage on the main filtering capacitors is
sensed with the voltage divider built around R2, R5, and R8 and is fed into the dedicated
control unit through the J2 connector. The proper voltage partitioning for applied resistor
values is 0.0075.

The presence of +15 VDC on the board is indicated with the D5 green LED "Power ON".
Figure 9 describes the power supply section with a simplified block diagram.

Figure 9. Power supply block diagram
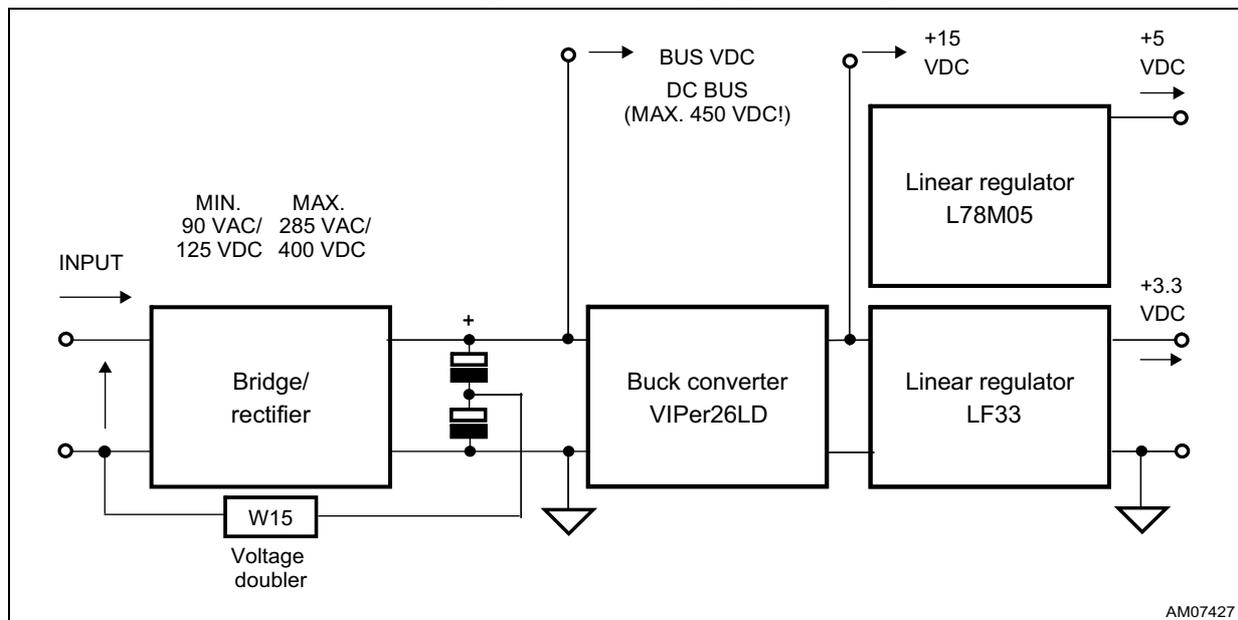
2.3.2 Inrush limitation

The input stage of the evaluation board is provided with an NTC resistor to eliminate input inrush current peak during the charging of the bulk capacitors. To achieve a higher efficiency of the inverter it is possible to bypass the NTC after the start-up phase. The NTC bypass signal is provided from the MCU board through the J2 connector. The yellow D10 LED diode "Current limiter" is turned off when the inrush NTC is bypassed.

A basic EMI filter based on X2 and Y2 capacitors was implemented on the board. The EMI filter is not able to absorb EMI distortion coming from the inverter for all ranges of the applications. The final EMI filter must be designed according to the motor and the design of the related EMI filter is up to the user according to the chosen motor and final target application. The heatsink itself is connected to the earth pin in the J1 connector. It is recommended to connect the heatsink to a negative voltage potential - common ground when a DC voltage is used to supply the evaluation board.

2.3.3 Power block based on IGBT module

The IGBT module STGIPS20C60 consists of high, rugged IGBT power switches and three smart drivers. STGIPS20C60 is provided with advanced gate smart drivers, many features are available, such as integrated comparators for overcurrent or short-circuit protection, and the "SMART SHUTDOWN" function. Please refer to the STGIPS20C60 datasheet for more information.

2.3.4 Brake function

A hardware brake feature is implemented on the STEVAL-IHM028V2 evaluationevaluation board. This feature connects the external resistive load, applied to the J7 connector, to the main supply bus to eliminate overvoltage generated while the motor acts as a generator. This connected load must be able to dissipate all motor generated energy. Almost any kind of high power resistor which may be used as dissipative load also has relative high parasitic inductance. Due to such inductance it is important to take care not to damage the brake Q8 IGBT switch with a freewheeling diode applied directly to the terminals of the dissipative power resistor used.

Voltage on the bus is sensed through a voltage divider net, with resistors R40, R41, and R48, and is compared to the precise voltage reference U5. The brake dummy load is switched on when the voltage on the bus reaches approximately 435 VDC and is switched off when the voltage falls bellows 415 VDC. This voltage level has been chosen to be fully compliant with the possible use of front-end PFC stage. The brake function can also be activated by the microcontroller through the J2 motor-control connector (PWM_Brake signal). For this configuration, the user should set the W2 jumper to position "A". The brake threshold levels can be modified by calculating R49 and R51 new values. D13 red LED diode "Brake" indicates the acting brake switch.

2.3.5 Overcurrent protection

Hardware overcurrent protection (OCP) is implemented on the board. This feature takes advantage of STGIPS20C60 intelligent module where an internal comparator is implemented. Thanks to the internal connection between the comparator output and shutdown block of the IPM, the intervention time of overcurrent protection is extremely low, ranging slightly above 200 ns. Please see *Figure 10* for details.

Overcurrent protection acts as soon as the voltage on the CIN pin rises above the internal voltage reference (typical value V_{REF_INT} is 0.53 V). Considering the default value of the OCP shunt resistor, it follows that the maximum allowed current is equal to:

Equation 1

$$I_{shunt\_MAX} = \frac{0.53 \times (R1 \times R2 + R2 \times R3 + R1 \times R3) - 3.3 \times R1 \times R2}{R_{LS} \times R2 \times R3}$$

With the default values this gives:

$I_{shunt\_MAX} \sim 20$ A

Figure 10. Overcurrent protection
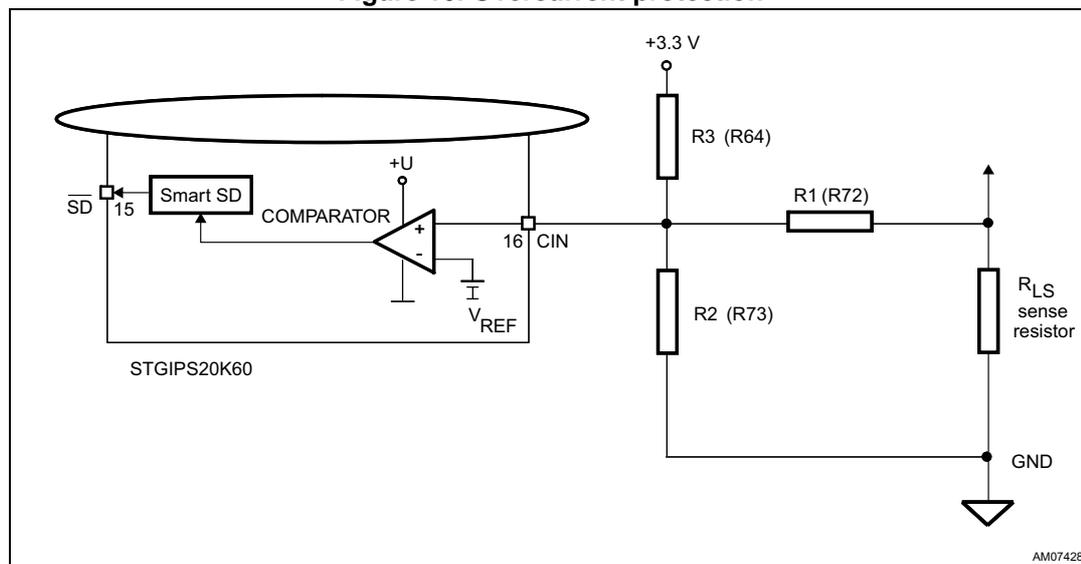
Overcurrent protection can be disabled if the W2 jumper is set to the "B" position. This may be necessary and is often useful when the user decides to make the brake operate by turning on the three low-side switches. In fact, if the motor acts as a generator, it is necessary to protect the hardware, preventing the bus voltage from exceeding a safety threshold. In addition to dissipating the motor energy on a brake resistor, it's possible to short the motor phases, preventing the motor current from flowing through the bulk capacitors. Please note that if the OCP is disabled, the evaluationevaluation board is not protected against any overcurrent event.

2.3.6 Current sensing amplifying network

The STEVAL-IHM028V2 motor control evaluation board can be configured to run in various current reading configuration modes:

- Three-shunt configuration - suitable for field oriented control (FOC)
- Single-shunt configuration - suitable for FOC in a single-shunt configuration
- Single-shunt - six-step configuration - suitable for scalar control.

Configuration with a shunt resistor, where voltage amplified with an operational amplifier is sensed, was chosen as current sensing networks. Single-shunt configuration requires a single op amp, three-shunt configuration requires three op amps. For compatibility purposes, one of them is common to both basic configurations.

The configuration jumpers W11, W12, W13, and W14 allow to set the common op amp to achieve compatibility between single-shunt six-step configuration (suitable for scalar control) and three-shunt or single-shunt FOC current reading configuration. The operational amplifier TSV994 used on amplifying networks has a 20 MHz gain bandwidth and operates with just a single positive supply of +5 V.

Three-shunt FOC or single-shunt FOC current reading configuration

Details of the FOC current-sensing reading configuration are shown in *Figure 11*. In this configuration, the alternating signal on the shunt resistor, with positive and negative values, must be converted to be compatible with the single positive input of the microcontroller A-D converter used to read the current value.

The op amp is used in symmetrical follower mode: its gain is set by resistors r and R:

Equation 2

$$r = \frac{(r1 + R_{LS}) \times r2}{r1 + R_{LS} + r2}$$

$$G = \frac{R + r}{r}$$

It is possible to calculate the voltage on the output of the op amp OP OUT - V_{OUT} as a sum of a bias V_{BIAS} and a signal V_{SIGN} component equal to:

Equation 3

$$V_{OUT} = V_{SIGN} + V_{BIAS}$$

$$V_{BIAS} = \frac{3.3}{\left(\dfrac{1}{R1} + \dfrac{1}{R2} + \dfrac{1}{R3}\right) \times R3} \times G$$

$$V_{SIGN} = \frac{I \times R_{HS}}{\left(\dfrac{1}{R1} + \dfrac{1}{R2} + \dfrac{1}{R3}\right) \times R1} \times G$$

Total gain of the circuit including the resistor divider is equal to:

Equation 4

$$G_{TOT} = \frac{V_{SIGN}}{V_{IN}} = \frac{V_{SIGN}}{R_{HS} \times I}$$

With the default values this gives:

- V_{BIAS} = 1.57 V
- Maximal voltage of V_{SIGN} = 1.56 V
- G = 5.38
- G_{TOT} = 3.90
- Maximum current amplifiable without distortion is 16 A.

Figure 11. Configuration for FOC

Table 1 shows the mentioned setting of gain jumpers for both FOC configurations.

Table 1. Gain settings for FOC current reading configuration

Setting for FOC configuration	Three-shunt configuration		Single-shunt configuration	
	W11	Present	W11	Present
Setting of gain	W12	Present	W12	Present
	W13	Present	W13	Present
	W14	Present	W14	Present

Six-step (block commutation) current reading configuration

In the case of six-step (also called block commutation) current control, only two of the motor phases conduct current at the same time. Therefore, it is possible to use only one shunt resistor placed on the DC link to measure the motor phase current. Furthermore, as the current is always flowing in the same direction on the shunt resistor, only positive current must be measured, and in this case the amplifying network needs to be properly designed. The details of single-shunt current sensing reading configuration are shown in *Figure 12*. In this configuration, the current sampling is done only when the value on the shunt resistor is positive. Only the positive value read on the shunt resistor allows the setting of a higher gain for the op amp than the one set in three-shunt reading mode.

The op amp is used in follower mode with gain of the op amp set by resistors:

Equation 5

$$r = \frac{(r1 + R_{LS}) \times r2}{r1 + R_{LS} + r2}$$

$$G = \frac{R + r}{r}$$

It is possible to calculate the voltage on the op amp output OP OUT - V_{OUT} as the sum of a bias V_{BIAS} and a signal V_{SIGN} component equal to:

Equation 6

$$V_{OUT} = V_{SIGN} + V_{BIAS}$$

$$V_{BIAS} = \frac{3.3}{\left(\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right) \times R3} \times G$$

$$V_{SIGN} = \frac{1 \times R_{HS}}{\left(\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}\right) \times R1} \times G$$

Total gain of the circuit with the resistor divider is equal to:

Equation 7

$$G_{TOT} = \frac{V_{SIGN}}{V_{IN}} = \frac{V_{SIGN}}{R_{HS} \times I}$$

With the default values this gives:

- V_{BIAS} = 0.38 V
- Maximal voltage of V_{SIGN} = 2.76 V
- G = 8.02
- G_{TOT} = 6.90
- Maximum current amplifiable without distortion is 16 A.

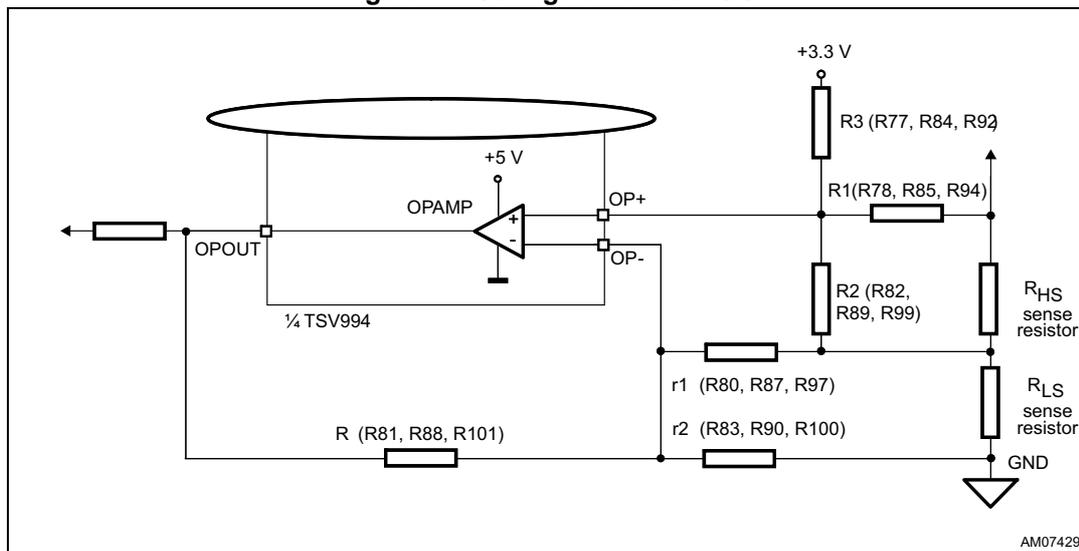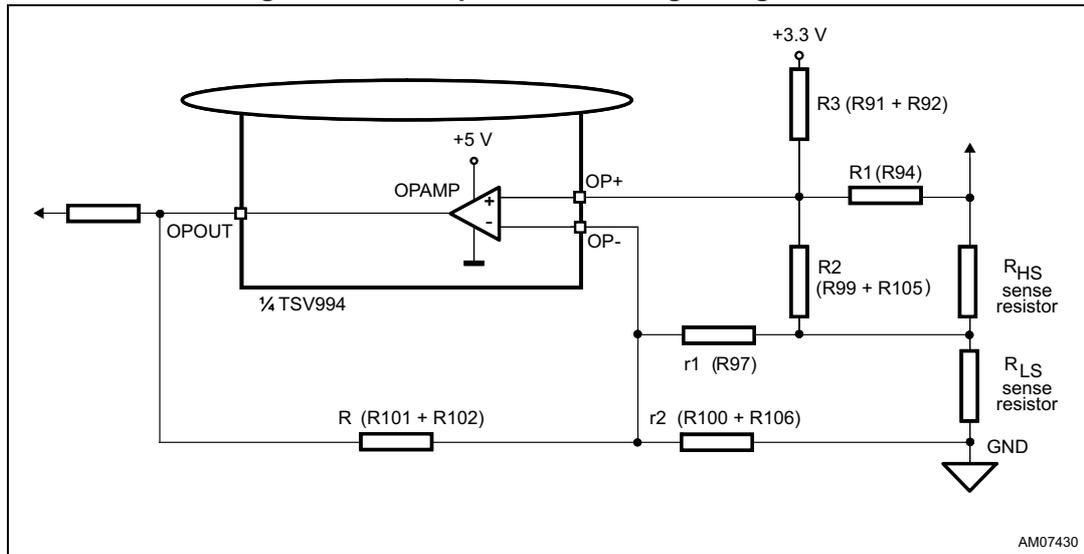**Figure 12. Six-step current sensing configuration**

Table 2 shows the mentioned setting of gain jumpers for this configuration.

Table 2. Gain settings for six-step current reading configuration

Setting for six-step configuration	Single-shunt configuration	
	W11	Not present
Setting of gain	W12	Not present
	W13	Not present
	W14	Not present

2.3.7 The tachometer and Hall/encoder inputs

Both the tachometer and Hall/encoder inputs have been implemented on the board. When using a Hall or encoder sensor, the W5 jumper must be connected and the W4 jumper disconnected. The W6 jumper set to position "A" allows to supply any connected Hall sensor with the same supply voltage as other hardware peripherals (+3.3 VDC or +5 VDC depending on the W1 jumper). Setting the W6 jumper to position "B" supplies the Hall sensor directly with +5 VDC, which is the most common voltage for a Hall sensor. The U4 Hex Schmitt inverter is used as the voltage level shifter for connected Hall sensors. If using a tachometer, jumper W5 must be disconnected and jumper W4 connected.

This type of adjustable feature allows the testing and evaluating of motors with a wide spectrum of various sensors.

2.3.8 Temperature feedback and overtemperature protection (OTP)

Hardware overtemperature protection is implemented on the STEVAL-IHM028V2 evaluation board. This feature fully protects the IPM module against damage when the temperature on the junction on the IPM surpasses a defined value. The temperature is sensed through an NTC resistor RT1. The measured signal is amplified with an operational amplifier and then fed through the J2 motor connector to the MCU control unit to be read with an A-D converter. The signal is also fed to the U9A comparator where it is compared with a 2.5 V reference voltage. The precision reference U10 TS3431 provides this 2.5 V reference

voltage. The output signal of the comparator is fed into the IPM to stop the commutation of the connected motor as well as into the MCU control unit through the J2 connector. With the value of the used resistor networks and applied NTC resistor, the shutdown temperature of the heatsink is somewhere between 85 °C and 90 °C.

2.3.9 Active heatsink cooling

For better thermal transfer of heat from the heatsink, active fan cooling is implemented on the board. The aluminum profile used is type 8424 from PADA Engineering. The temperature is sensed with the NTC resistor and compared with a reference voltage in comparator U9B. The fan is switched on automatically when temperature of the heatsink reaches approximately 40 °C and is switched off when temperature of the heatsink falls to 35 °C. The thermal resistance of the heatsink, when the fan is not activated, is visible in *Figure 13*, the thermal resistance with active fan cooling is visible in *Figure 14*.

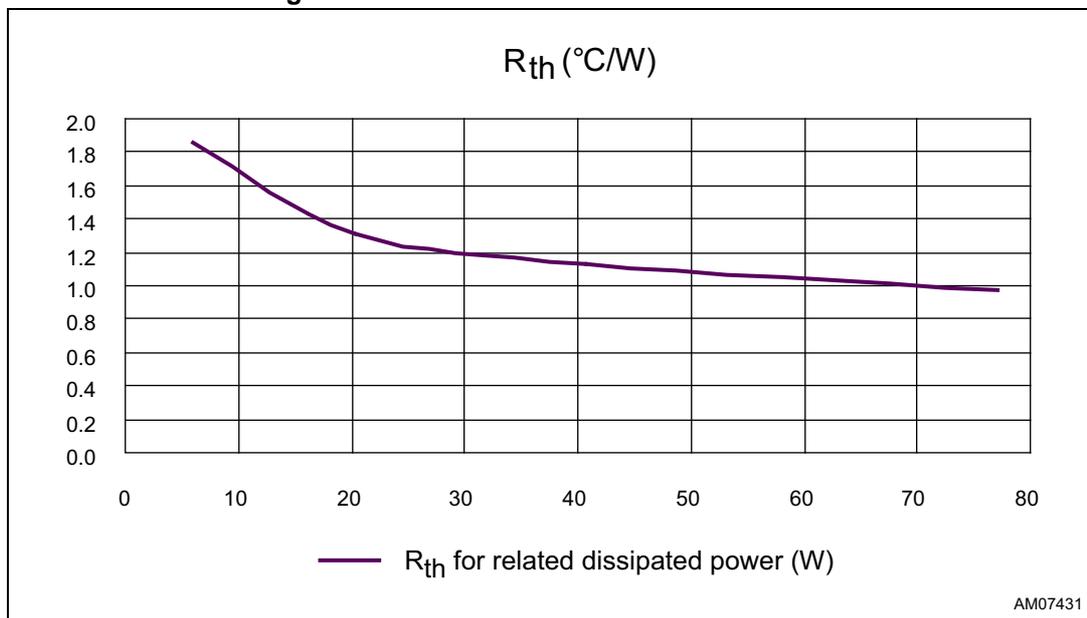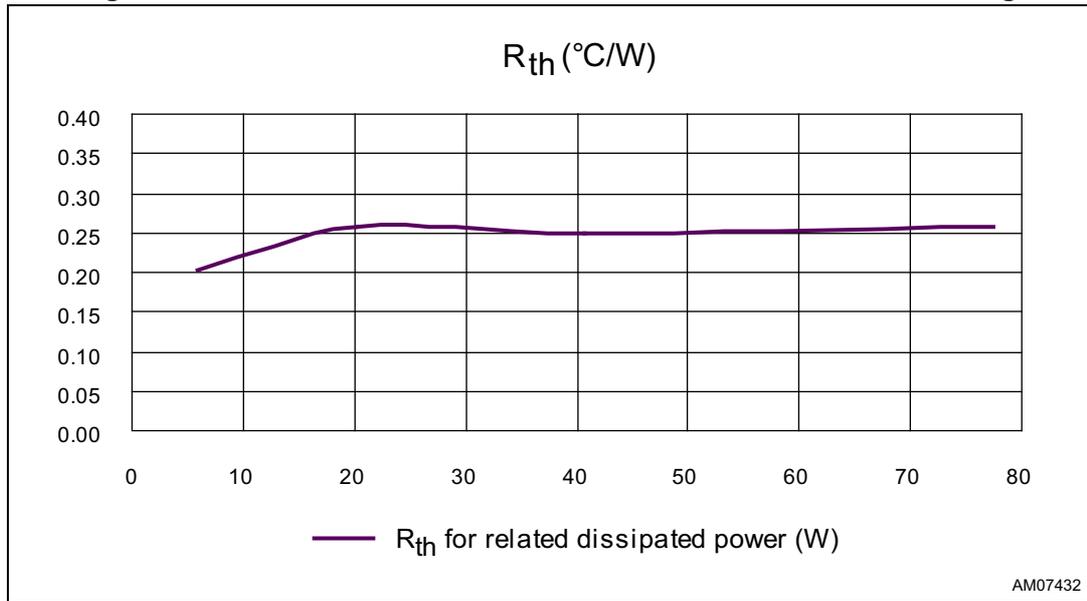**Figure 13. Thermal resistance of the heatsink**

Figure 14. Thermal resistance of the heatsink with continuous fan cooling

3 Hardware setting of the STEVAL-IHM028V2

The STEVAL-IHM028V2 evaluation board can be driven through the J2 motor connector by various STMicroelectronics MCU control units which feature a unified 34-pin motor connector. The evaluation board is suitable for field oriented control as well as for tachometer or Hall sensor closed-loop control. The STEVAL-IHM028V2 evaluation board ideally fits with the STM3210B-EVAL board based on the STM32 MCU family as the control unit for FOC-driving algorithms.

3.1 Hardware settings for six-step (block commutation) current control in single-shunt configuration

To drive any motor, the user must ensure that:

- The motor control evaluation board is driven by a control board which provides the six output signals required to drive the 3-phase power stage
- The motor is connected to the J4 motor output connector
- If using an encoder or Hall sensor connection, it is connected to connector J5
- If using a tachometer connection, it is connected to connector J6
- If using the brake control feature, connect a dissipative power load to connector J7.

Table 3 shows the jumper settings for any motors. Please confirm that the evaluation board input voltage is in the range of 125 VDC to 400 VDC or 90 VAC to 285 VAC.

Table 3. Jumper settings for PMSM or generic AC motor - six-step

Jumper	Settings for six-step current control
W1	A position for V_{DD} = 3.3 V
	B position for V_{DD} = 5 V
W2	A position for software brake
	B position for disabling OCP
W3	Not present
	Present - supply J2 with V_{DD} (max. 50 mA)
W4	Present for tachometer
	Not present for Hall / encoder
W5	Present for Hall / encoder
	Not present for tachometer
W6	A position - V_{DD} for Hall / encoder
	B position - +5 V for Hall / encoder
W7	Present
W8	Present
W9	Not present
W10	Not present

Table 3. Jumper settings for PMSM or generic AC motor - six-step

Jumper	Settings for six-step current control (continued)
W11	Not present
W12	Not present
W13	Not present
W14	Not present
W15	Present for voltage doubler (max. 145 VAC)
W15	Not present for normal supply range

3.2 Hardware settings for FOC in three-shunt configuration

To drive any motor, the user must ensure that:

- The motor control evaluation board is driven by a control board which provides the six output signals required to drive the 3-phase power stage
- The motor is connected to the J4 motor output connector
- If using an encoder or Hall sensor connection, it is connected to connector J5
- If using a tachometer connection, it is connected to connector J6
- If using the brake control feature, connect a dissipative power load to connector J7.

Table 4 shows the jumper settings for any motors. Please confirm that the evaluation board input voltage is in the range of 125 VDC to 400 VDC or 90 VAC to 285 VAC.

Table 4. Jumper settings for PMSM or generic AC motor - FOC in three-shunt

Jumper	Settings for FOC in three-shunt
W1	A position for V_{DD} = 3.3 V
W1	B position for V_{DD} = 5 V
W2	A position for software brake
W2	B position for disabling OCP
W3	Not present
W3	Present - supply J2 with V_{DD} (max. 50 mA)
W4	Present for tachometer
W4	Not present for tachometer / encoder
W5	Present for Hall / encoder
W5	Not present for tachometer
W6	A position - V_{DD} for Hall / encoder
W6	B position - +5 V for Hall / encoder
W7	Not present
W8	Not present
W9	Present
W10	Present

Table 4. Jumper settings for PMSM or generic AC motor - FOC in three-shunt

Jumper	Settings for FOC in three-shunt
W11	Present
W12	Present
W13	Present
W14	Present
W15	Present for voltage doubler (max. 145 VAC)
	Not present for normal supply range

3.3 Hardware settings for FOC in single-shunt configuration

To drive any motor, the user must ensure that:

- The motor control evaluation board is driven by a control board which provides the six output signals required to drive the 3-phase power stage
- The motor is connected to the J4 motor output connector
- If using an encoder or Hall sensor connection, it is connected to connector J5
- If using a tachometer connection, it is connected to connector J6
- If using the brake control feature, connect a dissipative power load to connector J7.

Table 5 shows the jumper settings for any motors. Please confirm that the evaluation board input voltage is in the range of 125 VDC to 400 VDC or 90 VAC to 285 VAC.

Table 5.   Jumper settings for PMSM or generic AC motor - FOC in single-shunt

Jumper	Settings for FOC in single-shunt
W1	A position for V_{DD} = 3.3 V
	B position for V_{DD} = 5 V
W2	A position for software brake
	B position for disabling OCP
W3	Not present
	Present - supply J2 with V_{DD} (max. 50 mA)
W4	Present for tachometer
	Not present for tachometer / encoder
W5	Present for Hall / encoder
	Not present for tachometer
W6	A position - V_{DD} for Hall / encoder
	B position - +5 V for Hall / encoder
W7	Present
W8	Present
W9	Not present
W10	Not present

Table 5.   Jumper settings for PMSM or generic AC motor - FOC in single-shunt

Jumper	Settings for FOC in single-shunt
W11	Present
W12	Present
W13	Present
W14	Present
W15	Present for voltage doubler (max. 145 VAC)
	Not present for normal supply range

4   Testing of the evaluation board

The overall test of the evaluation board was performed on a motor bench with two kinds of applied PMAC motors. Test conditions are listed below.

Parameters for 1st test

Motor parameters:
- Manufacturer: Reel S.r.l.
- Type: IB100 F
- Nominal power: 10.7 kW
- 4-pole pairs
- $L_s = 0.003465$ H; $R_s = 0.28$ Ω
- $K_e = 84$ V
- Nominal speed: 3000 rpm

Test conditions:
- Supply voltage 325 VAC; frequency 50 Hz
- Testing output power 1.8 kW; testing speed 1000 rpm
- Temperature of ambient 22 °C
- Active fan cooling disabled; plastic covers removed

Parameters for 2nd test

Motor parameters:
- Manufacturer: DOMEL
- Type: 748.3.292
- Nominal power: 1.6 kW
- 4-pole pairs
- $L_s = 0.045$ H; $R_s = 1.03$ Ω
- $K_e = 84$ V
- Nominal speed: 2250 rpm

Test conditions:
- Supply voltage 325 VAC; frequency 50 Hz
- Testing output power 1.6 kW; testing speed 2250 rpm
- Ambient temperature 22 °C
- Active fan cooling disabled; plastic covers removed

The STM3210B board was used as the control unit with STM32 FOC firmware library v2.0 loaded. The flux weakening strategy with no sensors was chosen for testing. Three-shunt resistors current sensing technique was selected. All related parameters of the motor were included in the source code via the FOCGUI 2.0.0 application.

The duration of the tests was 45 minutes with the mentioned continuous output power measured on the load of the motor testing stand. For correct thermal measurements of the heatsink temperature, the assembled fan was removed together with the plastic covers. Measured parameters, visible in *Figure 15*, were taken with the type IB100 F motor.

Figure 15. Current signals
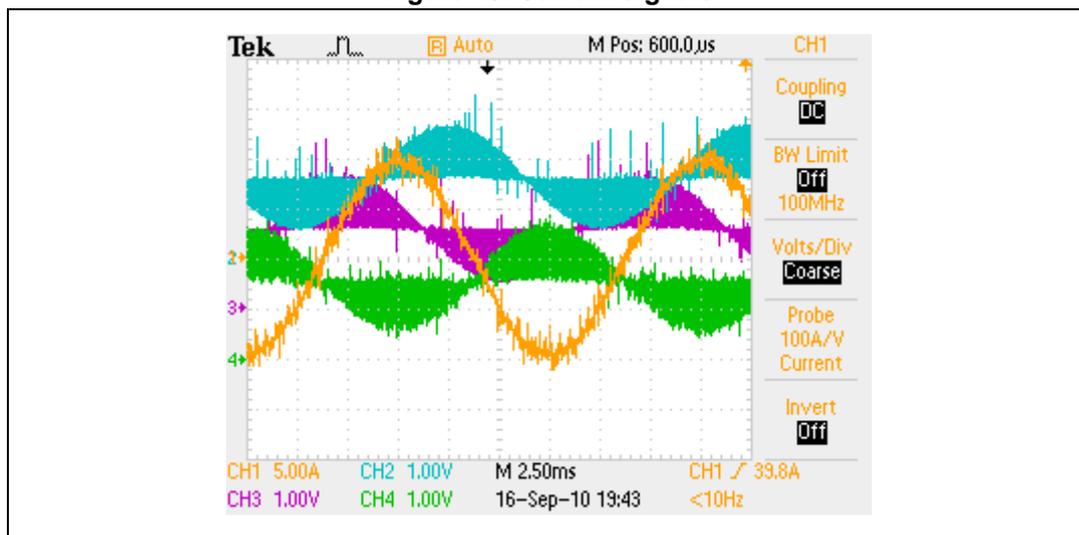
1. Ch1 - Output phase current, current probe on phase C
   Ch2 - voltage on TP19, phase current A
   Ch3 - voltage on TP21, phase current B
   Ch4 - voltage on TP22, phase current C.

5   Description of jumpers, test pins, and connectors

Table 6, *7*, and *8* give a detailed description of the jumpers, test pins, and the pinout of the connectors used.

Table 6.   Jumper description

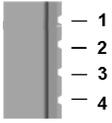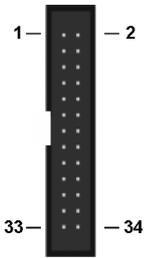| Jumper	Selection	Description
W1	A position	V_{DD} = 3.3 V
	B position	V_{DD} = 5 V
W2	A position	Software brake applied
	B position	Disabling of OCP
W3	Present	Supplying of MCU unit with V_{DD}
	Not present	MCU is supplied separately
W4	Present	Tachometer connected
	Not present	Hall or encoder connected
W5	Present	Hall or encoder connected
	Not present	Tachometer connected
W6	A position	A position - V_{DD} for Hall / encoder
	B position	B position - +5 V for Hall / encoder
W7	Present	Any single-shunt configuration
	Not present	Any three-shunt configuration
W8	Present	Any single-shunt configuration
	Not present	Any three-shunt configuration
W9	Present	Any three-shunt configuration
	Not present	Any single-shunt configuration
W10	Present	Any three-shunt configuration
	Not present	Any single-shunt configuration
W11	Present	Gain for any FOC
	Not present	Gain for six-step control
W12	Present	Gain for any FOC
	Not present	Gain for six-step control
W13	Present	Gain for any FOC
	Not present	Gain for six-step control
W14	Present	Gain for any FOC
	Not present	Gain for six-step control
W15	Present	Voltage doubler applied (max. 145 VAC)
	Not present	Voltage doubler disabled

Table 7. Connector pinout description

Name	Reference	Description / pinout
J1		**Supply connector** 1 - L - phase 2 - N- neutral 3 - PE- protected earth 4 - PE- protected earth
J2		**Motor control connector**

For J2 (Description / pinout):

1 - emergency stop	2 - GND
3 - PWM-1H	4 - GND
5 - PWM-1L	6 - GND
7 - PWM-2H	8 - GND
9 - PWM-2L	10 - GND
11 - PWM-3H	12 - GND
13 - PWM-3L	14 - HV bus voltage
15 - current phase A	16 - GND
17 - current phase B	18 - GND
19 - current phase C	20 - GND
21 - NTC bypass relay	22 - GND
23 - dissipative brake PWM	24 - GND
25 - +V power	26 - heatsink temperature
27- PFC sync.	28 - $V_{DD\_}m$
29 - PWM V_{REF}	30 - GND
31 - measure phase A	32 - GND
33 - measure phase B	34- measure phase C
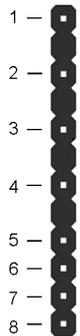
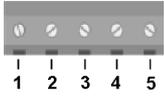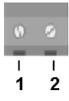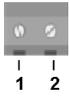| Name	Reference	Description / pinout
J3		**BEMF daughterboard connector** 1 - phase A 2 - phase B 3 - phase C 4 - bus voltage 5 - 3.3 VDC 6 - $V_{DD\_}$micro 7 - GND 8 - PWM V_{REF}
J4		**Motor connector** A - phase A B - phase B C - phase C

Table 7. Connector pinout description (continued)

Name	Reference	Description / pinout
J5	 1 2 3 4 5	**Hall sensors / encoder input connector** 1 - Hall sensor input 1 / encoder A+ 1 - Hall sensor input 2 / encoder B+ 1 - Hall sensor input 3 / encoder Z+ 4 - 5 VDC 5 - GND
J6	 1 2	**Tachometer input connector for AC motor speed loop control** 1 - tachometer bias 2 - tachometer input
J7	 1 2	**Dissipative brake** 1 - open collector 2 - +bus voltage

Table 8. Testing pins description

Number	Description
TP1	Output phase A
TP2	Heatsink temperature
TP3	Output phase B
TP4	Sensed encoder / Hall signal H1/A+
TP5	Output phase C
TP6	Sensed encoder / Hall signal H2/B+
TP7	PWM - phase A - low-side
TP8	Sensed encoder / Hall signal H3/Z+
TP9	PWM - phase A - high-side
TP10	Voltage of the bus
TP11	PWM - phase B - low-side
TP12	Brake flag; when GND - brake switch activated
TP13	PWM - phase B - high-side
TP14	3.3 VDC
TP15	PWM - phase C - low-side
TP16	15 VDC
TP17	PWM - phase C - high-side
TP18	2.5 VDC - reference voltage
TP19	Current in phase A
TP20	GND

Table 8. Testing pins description

Number	Description
TP21	Current in phase B
TP22	Current in phase C

6 Connector placement

A basic description of the placement of all connectors on the board is visible in *Figure 16*.

Figure 16. STEVAL-IHM028V2 connector placement
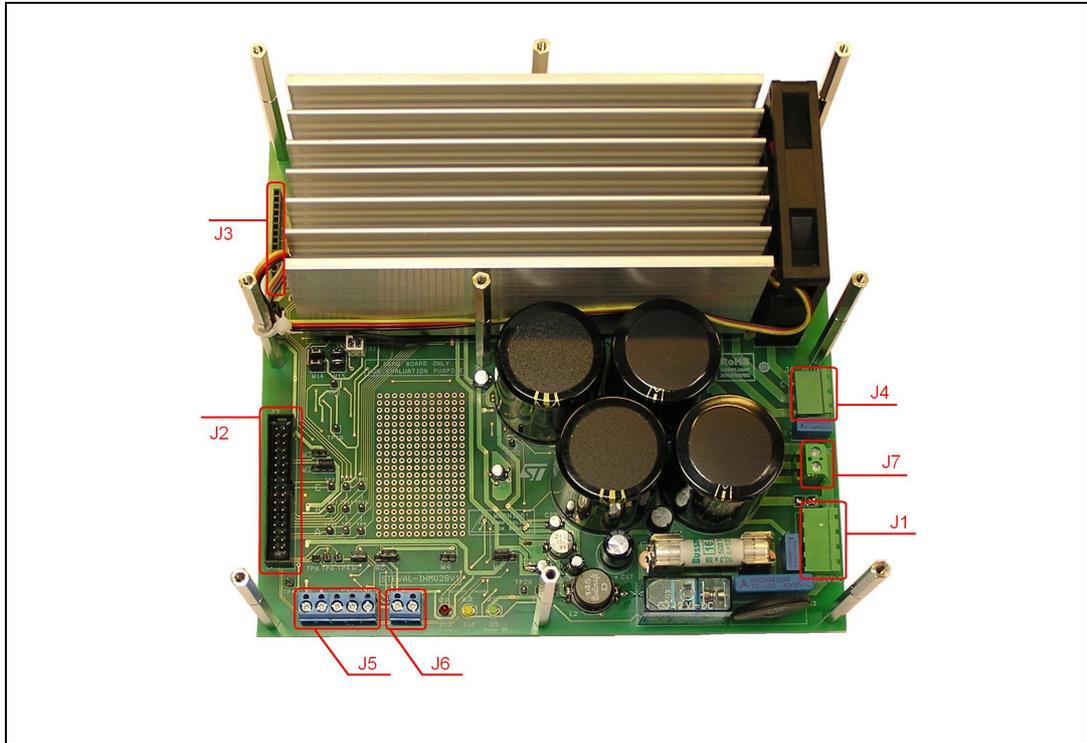
7 Bill of materials

A list of components used to build the evaluation board is shown in *Table 9*. The majority of the active components used are available from STMicroelectronics.

Table 9. Bill of materials

Qty	Reference	Value / generic part number	Package / class	Manufacturer
2	C1, C6	4.7 nF / Y2	Y2 safety CAP - 4n7	Murata Manufacturing Co., Ltd.
4	C2, C3, C4, C75	1500 µF / 250 V	Elyt. 35 x 50	EPCOS B43540E2158M000
1	C5	150 nF / X2	X2 cap; 6 x 15 x 26,5	EPCOS B32923C3154K
2	C7, C72	10 nF	Capacitor, SMD 0805	Any
23	C8, C9, C11, C12, C14, C19, C22, C23, C24, C25, C26, C27, C29, C30, C34, C35, C36, C38, C41, C64, C66, C70, C73	100 nF	Capacitor, SMD 0805	Any
2	C10, C13	47 µF / 4 V	Elyt. capacitor, SMD 4*4	Any
2	C28, C65	22 µF / 6.3 V	Elyt. capacitor, SMD 4*4	Any
0	C15	N.C.		
1	C16	220 nF	Capacitor, SMD 0805	Any
1	C17	3.3 µF / 450 V	Elyt. capacitor, 10x20	Any
1	C18	1 µF / 50 V	Elyt. capacitor, SMD 4*4	Any
1	C20	100 µF / 25 V	Elyt. capacitor, SMD 8*8	Any
2	C21, C40	4.7 µF / 35 V	Elyt. capacitor, SMD 4*4	Any
9	C31, C32, C33, C44, C45, C51, C52, C54, C55	10 pF	Capacitor, SMD 0805	Any
2	C37, C56	2.2 nF	Capacitor, SMD 0805	Any
1	C39	470 pF	Capacitor, SMD 0805	Any
1	C42	4.7 nF	Capacitor, SMD 0805	Any
5	C43, C60, C63, C69, C74	100 pF	Capacitor, SMD 0805	Any
6	C46, C47, C48, C49, C50, C53	1 µF	Capacitor, SMD 1206; 50 V	AVX
2	C57, C71	330 pF	Capacitor, SMD 0805	Any
6	C58, C59, C61, C62, C67, C68	47 pF	Capacitor, SMD 0805	Any
1	RT1	10 kΩ	NTC, 10 kΩ, handle under screw	EPCOS B57703M 103G 40

Table 9. Bill of materials (continued)

Qty	Reference	Value / generic part number	Package / class	Manufacturer
3	R1, R4, R7	100 kΩ	Resistor, SMD 1206	Any
3	R53, R57, R61	100 kΩ	Resistor, SMD 0805, 1%	Any
4	R2, R5, R40, R41	470 kΩ	Resistor, SMD 1206	Any
1	R3	10 Ω	NTC resistor 10R, through hole	EPCOS B57464S0100M
2	R6, R10	120 Ω	Resistor, SMD 0805, 1%	Any
2	R8, R111	7.5 kΩ	Resistor, SMD 0805, 1%	Any
3	R9, R91, R106	51 kΩ	Resistor, SMD 0805, 1%	Any
1	R11	13 kΩ	Resistor, SMD 0805, 1%	Any
4	R12, R16, R31, R37	5.6 kΩ	Resistor, SMD 0805, 1%	Any
1	R13	160 Ω	Resistor, SMD 1206	Any
20	R14, R36, R44, R79, R86, R95, R103, R54, R55, R58, R59, R62, R63, R72, R78, R80, R85, R87, R94, R97	1 KΩ	Resistor, SMD 0805, 1%	Any
7	R15, R27, R28, R29, R50, R76, R93	10 kΩ	Resistor, SMD 0805, 1%	Any
9	R17, R18, R19, R20, R21, R22, R23, R24, R25	4.7 kΩ	Resistor, SMD 0805, 1%	Any
0	R26, R43	N.C.		Any
1	R30	100 Ω	Resistor, SMD 0805, 1%	Any
8	R32, R98, R77, R83, R84, R90, R92, R100	8.2 kΩ	Resistor, SMD 0805, 1%	Any
4	R33, R49, R51, R114	15 kΩ	Resistor, SMD 0805, 1%	Any
1	R34	6.8 kΩ	Resistor, SMD 0805, 1%	Any
2	R35, R109	910 Ω	Resistor, SMD 0805, 1%	Any
2	R47, R96	220 Ω	Resistor, SMD 0805, 1%	Any
1	R38	22 Ω	Resistor, SMD 0805, 1%	Any
1	R39	68 kΩ	Resistor, SMD 0805, 1%	Any
1	R42	560 Ω	Resistor, SMD 0805, 1%	Any
4	R45, R108, R110, R117	2.2 kΩ	Resistor, SMD 0805, 1%	Any
1	R115	4.3 kΩ	Resistor, SMD 0805, 1%	Any
1	R46	220 kΩ	Resistor, SMD 0805, 1%	Any
2	R48, R52	27 kΩ	Resistor, SMD 0805, 1%	Any
5	R56, R60, R65, R116, R73	3.3 kΩ	Resistor, SMD 0805, 1%	Any
1	R64	16 kΩ	Resistor, SMD 0805, 1%	Any

Table 9. Bill of materials (continued)

Qty	Reference	Value / generic part number	Package / class	Manufacturer
8	R66, R67, R68, R69, R70, R71, R74, R75	0.05 Ω	Resistor, SMD 2512, 1%, 2 W	Welwyn
6	R81, R82, R88, R89, R99, R101	3.9 kΩ	Resistor, SMD 0805, 1%	Any
2	R102, R105	3 kΩ	Resistor, SMD 0805, 1%	Any
1	R104	2.7 kΩ	Resistor, SMD 0805, 1%	Any
1	R107	180 Ω	Resistor, SMD 0805, 1%	Any
1	R112	1.2 kΩ	Resistor, SMD 0805, 1%	Any
1	R113	120 kΩ	Resistor, SMD 0805, 1%	Any
1	R118	1.8 kΩ	Resistor, SMD 0805, 1%	Any
1	D1	GBPC3510W	Diode bridge 28.5 x 28.5 x 7.5; wire legs, 35 A	Any
8	D2, D8, D11, D12, D15, D16, D17, D18	BAT48JFILM	Diode SMD	STM
3	D3, D9, D19	1N4148	Diode SMD, MINI-MELF	Any
2	D4, D6	STTH1L06A	Diode SMD, SMA	STM
1	D13	LED Red	LED 3 mm, 2 mA, universal	Any
1	D7	BZV55C18SMD	Zener diode 18 V, MINI-MELF	Any
1	D10	LED yellow	LED 3 mm, 2 mA, universal	Any
1	D5	LED green	LED 3 mm, 2 mA, universal	Any
1	D14	BZX84B13V	Zener diode, SOT23, 13 V; 2%	Any
10	Q1, Q2, Q3, Q4, Q5, Q7, Q9, Q10, Q11, Q12	BC847A	NPN transistor, SOT23	Any
1	Q6	BC857B	PNP transistor, SOT23	Any
1	Q8	STGW35NB60SD	TO-247	STM
1	Q13	BC807-25 SMD	PNP transistor 45 V / 0,5 A, SOT23	FAIRCHILD
1	L1	330 µH	Inductive choke RM 5 mm	Coilcraft
1	L2	1.5 mH	SMD choke, 1.5 mH / 1.5 A	Coilcraft
1	U1	LF33ABDT-TR	Linear regulator DPAK	STM
1	U2	VIPer26LD	PWM smart driver, SO-16	STM
1	U3	L78M05AB	Linear regulator DPAK	STM
1	U4	M74HC14R	CMOS logic, SO-14	STM
2	U5, U10	TS3431BILT	Voltage reference, SOT23	STM
1	U6	TS391ILT	Op amp, SOT23-5	STM
1	U7	STGIPS20C60	IPM IGBT module	STM

Table 9. Bill of materials (continued)

Qty	Reference	Value / generic part number	Package / class	Manufacturer
1	U8	TSV994IDT	Op amp, SO-14	STM
1	U9	TS372ID	Dual comparator, SO-8	STM
0	TP1, TP3, TP5	N.C.		
19	TP2, TP4, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22	PCB terminal 1 mm	Test pin	
	W1	Jumper 2.54	Three pins of pin header + jumper in position A	
	W2	Jumper 2.54	Three pins of pin header + jumper in position A	
	W3	Jumper 2.54	Two pins of pin header	
	W4	Jumper 2.54	Two pins of pin header	
	W5	Jumper 2.54	Two pins of pin header + jumper	
	W6	Jumper 2.54	Three pins of pin header + jumper in position A	
	W7	Jumper 2.54	N.C.	
	W8	Jumper 2.54	N.C.	
	W9	Jumper 2.54	Soldered PCB pads together	
	W10	Jumper 2.54	Soldered PCB pads together	
	W11	Jumper 2.54	Two pins of pin header + jumper	
	W12	Jumper 2.54	Two pins of pin header + jumper	
	W13	Jumper 2.54	Two pins of pin header + jumper	
	W14	Jumper 2.54	Two pins of pin header + jumper	
	W15	Jumper 2.54	N.C.	
1+1	J1	Connector 4P	Connector RM 5 mm, 4-pole male and female	Hartman
1	J2	MLW34G	MLW connector 34-pins	ARK
1	J3	BL815G	Pins RM 2.54 mm, (12-pins from 15-pin list)	
1+1	J4	Connector 3P	Connector RM5 mm, 3-pole male and female	Hartman
1+1	J5	Con. 5 mm, 2P + 3P	Connector RM 5 mm, 2-pole and 3-pole, screw	ARK
1	J6	Con. 5 mm, 2P	Connector RM 5 mm, 2-pole, screw	ARK
1	J7	Con. 5 mm, 2P	Connector RM 5 mm, 2-pole, screw	ARK

Table 9. Bill of materials (continued)

Qty	Reference	Value / generic part number	Package / class	Manufacturer
1	LS1	Finder 4061	Relay 12 V; 16 A / 250 VAC	Finder
1	FAN1	Connector 2.54 / 3P	PSH02-03PG	
2	F1	PA-PZ1008	Fuse holder 10 x 38; 2 pc in one board	
1		Fuse 16 A, high cur.	P = 16 A / 120 kA - 500 V; 10 x 38	
150 mm	Heatsink	Heatsink	150 mm of AL profile 8424 (65 x 70)	PADA Engineering
1		AIREN red wings 70	Fan 12 V; 70 mm x 70 mm x 15 mm	Airen

8 PCB layout

For this application a standard, double-layer, coppered PCB with a ~60 μm copper thickness was selected. The PCB material is FR-4.

The dimensions of the board are:

- Length: 195 mm
- Width: 175 mm
- PCB thickness: 1.55 mm

Figure 17. Copper tracks - top side
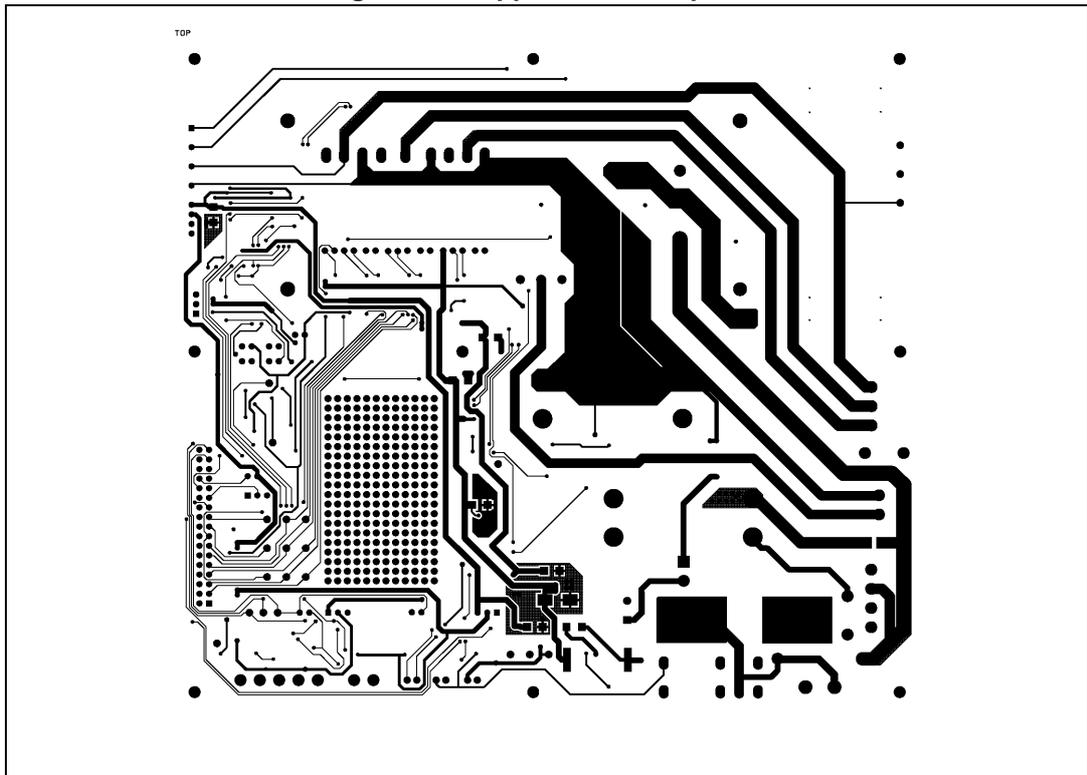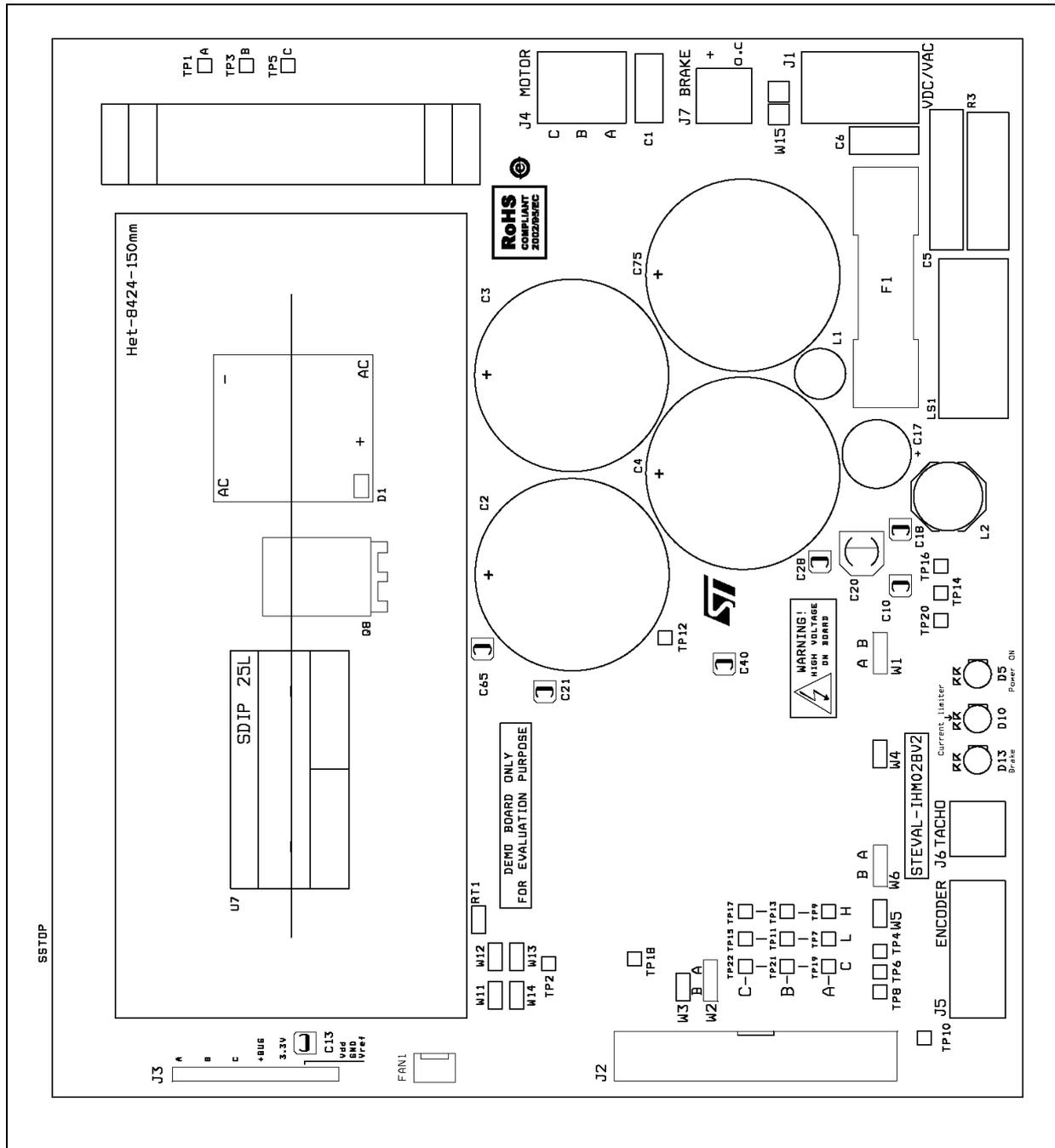
Figure 18. Copper tracks - bottom side
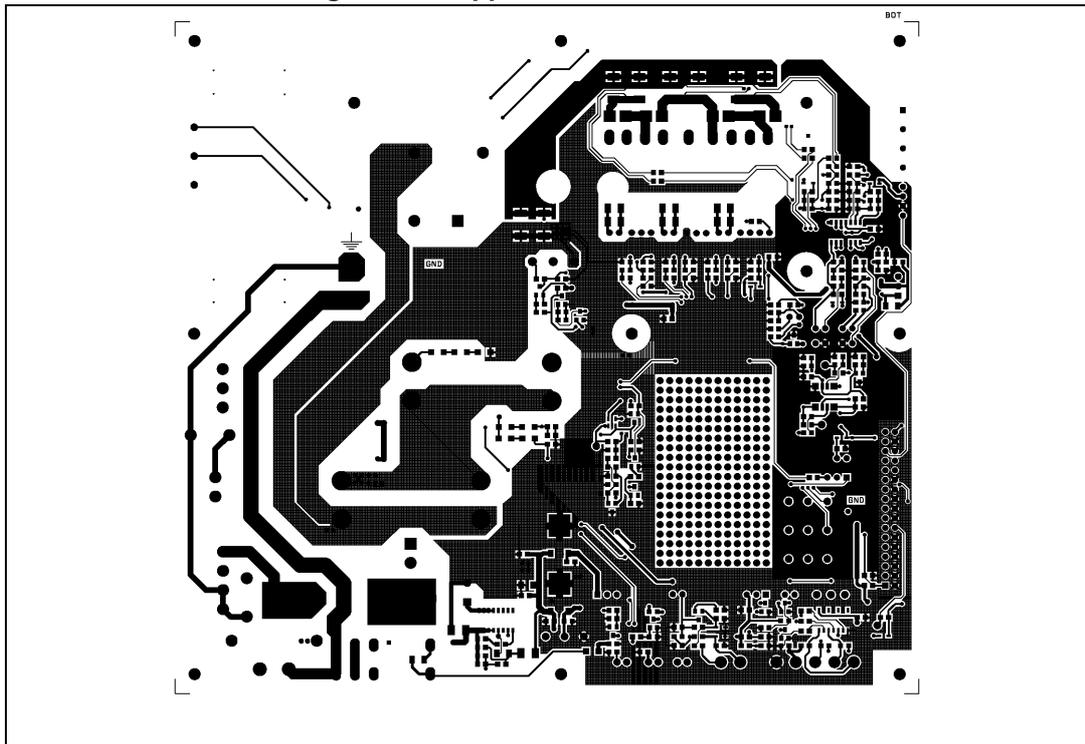
Figure 19. Silk screen - top side

Figure 20. Silk screen - bottom side

9 Ordering information

The evaluation board is available through the standard ordering system, the ordering code is: STEVAL-IHM028V2. The items delivered include the assembled application board, board documentation, PCB fabrication data, such as gerber files, assembly files (pick and place), and component documentation.

10 Using STEVAL-IHM028V2 with STM32 FOC firmware library

STM32 FOC firmware library (UM1052) is a firmware library which allows performing of the FOC of a PMSM in configuration with and without sensors.

10.1 Environmental considerations

Warning: **The STEVAL-IHM028V2 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: **All measuring 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 shock 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 can be found in the AN438 application note. (Although this application note was written for a TRIAC, the isolation constraints still apply for switching semiconductor devices such as IGBT or MOSFET).

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

10.2 Hardware requirements

To run the STEVAL-IHM028V2 together with the STM32 FOC firmware library, the following is required:

- The board: STEVAL-IHM028V2
- High voltage insulated AC power supply up to 230 VAC
- J-Link programmer - ST Link (not included in the package)
- J-Link insulating board (not included in the package)
- 3-phase brushless motor with permanent magnet rotor (not included in the package)
- Insulated oscilloscope (as required)
- Insulated multimeter (as required).

10.3 Software modifications

The most convenient way to edit the parameters header file is through the use of the ST MC Workbench (PC GUI configuration tool for the STM32 PMSM FOC SDK motor control firmware library.

11 Conclusion

This document describes the 2 kW 3-phase motor control STEVAL-IHM028V2 evaluation board based on IPM as a universal fully-evaluated and adaptable motor control platform.

12 References

1. STGIPS20C60 datasheet
2. VIPer26 datasheet
3. STGW35NB60SD datasheet
4. UM0379 user manual
5. UM0580 user manual
6. UM0723 user manual
7. UM0900 user manual

13 Revision history

Table 10. Document revision history

Date	Revision	Changes
13-Jan-2011	1	Initial release.
13-Nov-2014	2	Add new reference product.

IMPORTANT NOTICE – PLEASE READ CAREFULLY