

1 kW 3-phase motor control demonstration board featuring IGBT intelligent power module STGIPL14K60 STEVAL-IHM025V1

1 Introduction

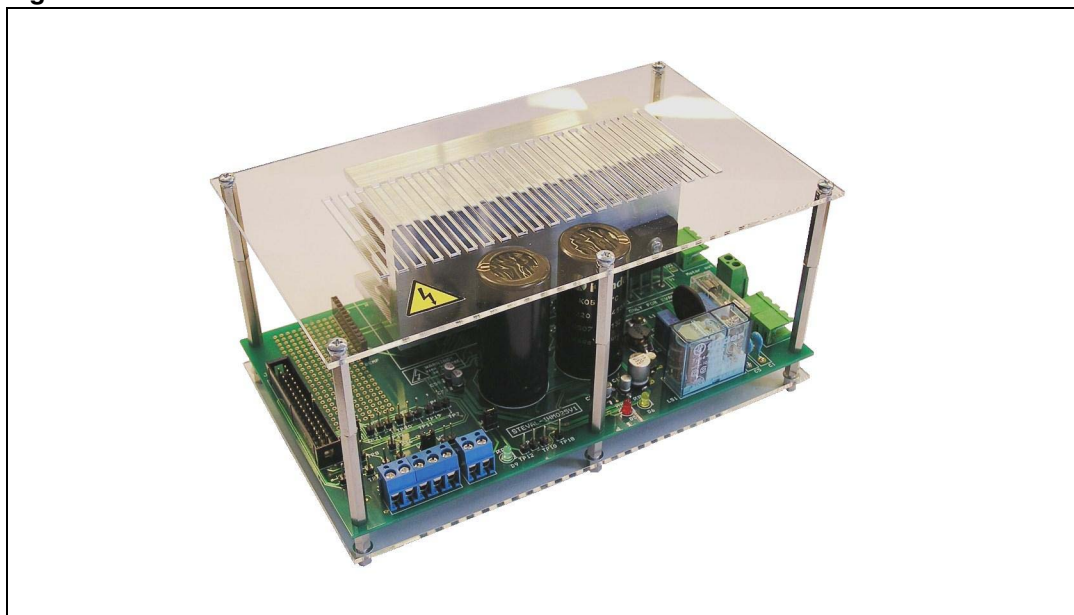
This document describes the 1 kW 3-phase motor control demonstration board featuring the IGBT intelligent power module STGIPL14K60. The demonstration board is an AC-DC inverter that generates a 3-phase waveform for driving 3- or 2-phase motors such as induction motors or PMSM motors up to 1000 W, with 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 38L package mounted on heatsink. STGIPL14K60 integrates: high voltage, short-circuit rugged IGBT and high voltage gate drivers with advanced features like integrated op-amp suitable for advanced current sensing. Thanks to this integrated module, the system has been specifically designed to achieve power inversion in a reliable and compact design. The system architecture of the module based on integrated advanced features is specifically designed to achieve an accurate and fast conditioning of the current feedback therefore matching the typical requirements in field oriented control (FOC).

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 DC voltage.

This document is associated with the release of the demonstration board STEVAL-IHM025V1 (see [Figure 1](#) below).

Figure 1. STEVAL-IHM025V1



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2 System introduction

2.1 Main characteristics

The information below lists the converter specification data and the main parameters set for the STEVAL-IHM025V1 demonstration board.

- Minimum input voltage 125 VDC or 90 VAC
- Maximum input voltage 400 VDC or 285 VAC
- Maximum output power for motors up to 1000 W
- Regenerative brake control feature
- Input inrush limitation with bypassing relay
- +15 V auxiliary power supply based on a buck converter with VIPer™16
- Use of the IGBT intelligent power module STGIPL14K60 in the SDIP 38L molded package
- Fully populated board conception with testing points and safety isolated plastic cover
- Motor control connector for interfacing with the STM3210B-EVAL board and other STMicroelectronics' motor control dedicated kits
- Tachometer input
- Hall/encoder inputs
- Possibility to connect a BEMF daughterboard for sensorless six-step control
- PCB type and size:
 - Material of PCB - FR-4
 - Double-sided layout
 - Copper thickness: ~45 µm
 - Total dimensions of demonstration board: 190 mm x 110 mm.

2.2 Target application

- Washing machines
- Home appliances
- Medical application, fitness application
- High-power industry pumps
- Medium power fans for HVAC
- Power tools.

2.3 Safety and operating instructions

2.3.1 General terms

Warning: During assembly, testing, and normal operation, the demonstration board poses several inherent hazards, including bare wires, moving or rotating parts and hot surfaces. There is a danger of serious personal injury if the kit or components are improperly used or incorrectly installed. The kit is not electrically isolated from the AC/DC input. The demonstration board is directly linked to the mains voltage. No insulation is ensured between accessible parts and high voltage. All measuring equipment must be isolated from the mains before powering the board. When using an oscilloscope with the demonstration board, 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 demonstration 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.

2.3.2 Demonstration board intended use

The STEVAL-IHM025V1 demonstration board is designed for demonstration 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.

2.3.3 Demonstration board installation

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

- The motor drive converters must 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 must be made with other electronic components and contacts.
- The boards contain electro-statically sensitive components that are prone to damage through improper use. Electrical components must not be mechanically damaged or destroyed.

2.3.4 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 demonstration 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).

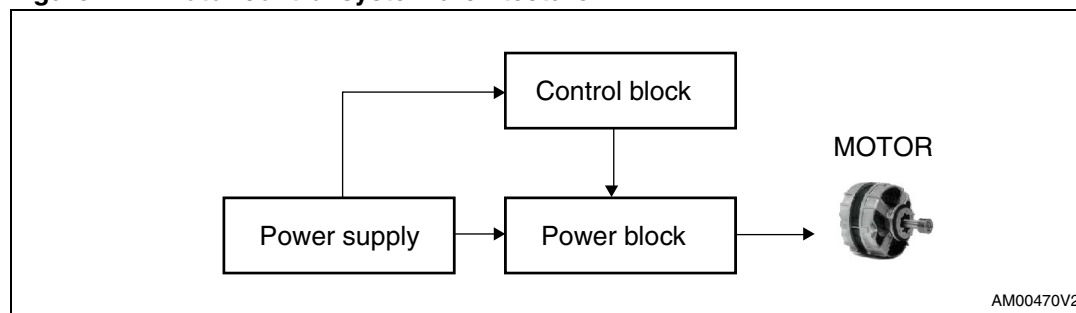
3 Board description

3.1 System architecture

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

- **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 demonstration board, based on the STM32 microcontroller can be used as the control block, thanks to the motor control connector equipped on the STEVAL-IHM025V1.
- **Power block** - it is based on three-phase inverter topology. The heart of the power block is the STGIPL14K60 integrated intelligent power module which contains all the necessary active components. Please refer to the STGIPL14K60 datasheets for more information.
- **The motor** - the STEVAL-IHM025V1 demonstration board is able to properly drive any PMSM, but the FOC itself is conceived for sinusoidal-shaped back-EMF. The demonstration board is also convenient for driving any 3- or 2-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 VIPer16 controller. Please refer to [Section 4](#) to properly set the jumpers according to the required application.

Figure 2. Motor control system architecture



The STEVAL-IHM025V1 includes the power supply and the power block.

Figure 3. STEVAL-IHM025V1 schematic - part 1

Figure 3. STEVAL-IHM025V1 schematic - part 1

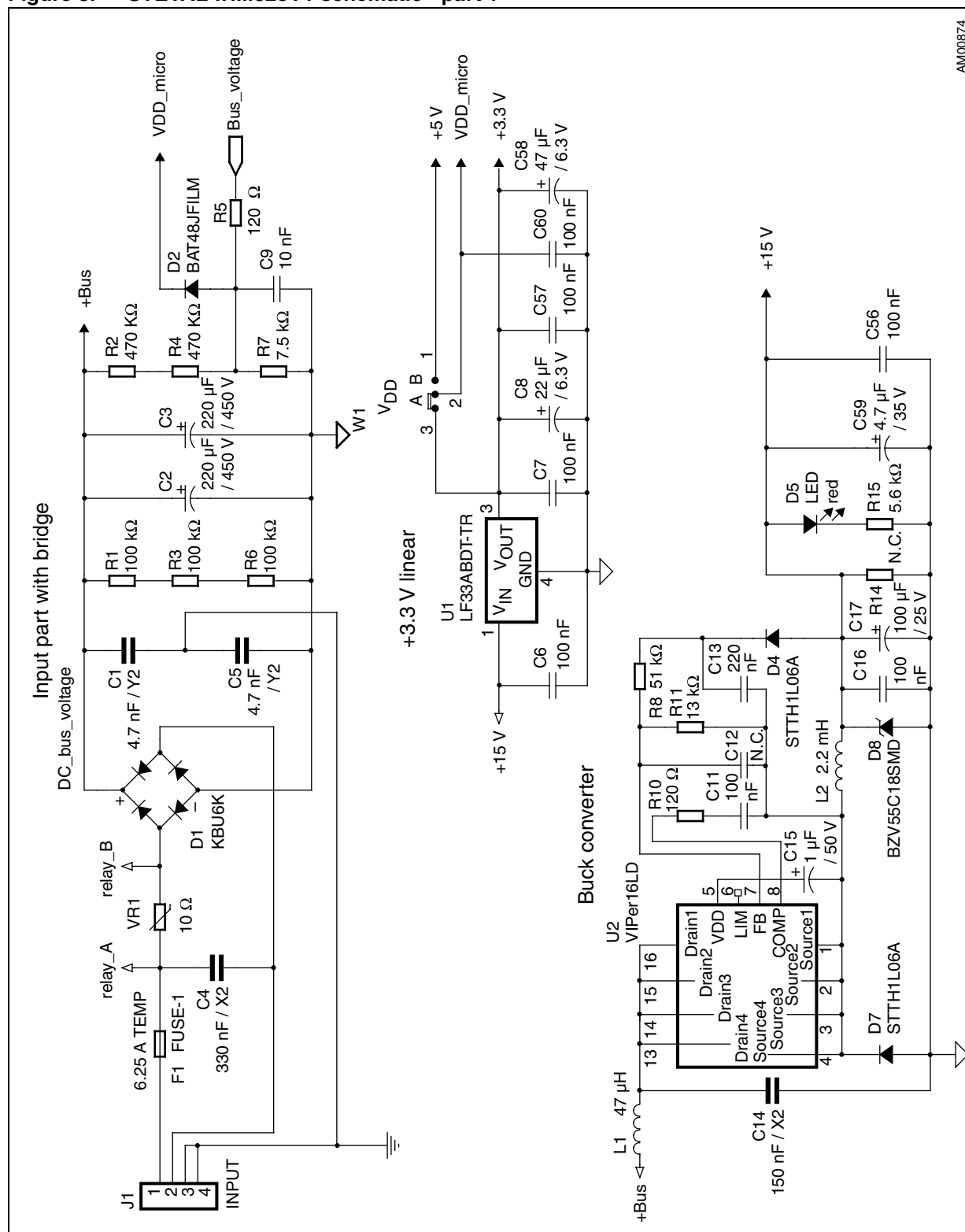
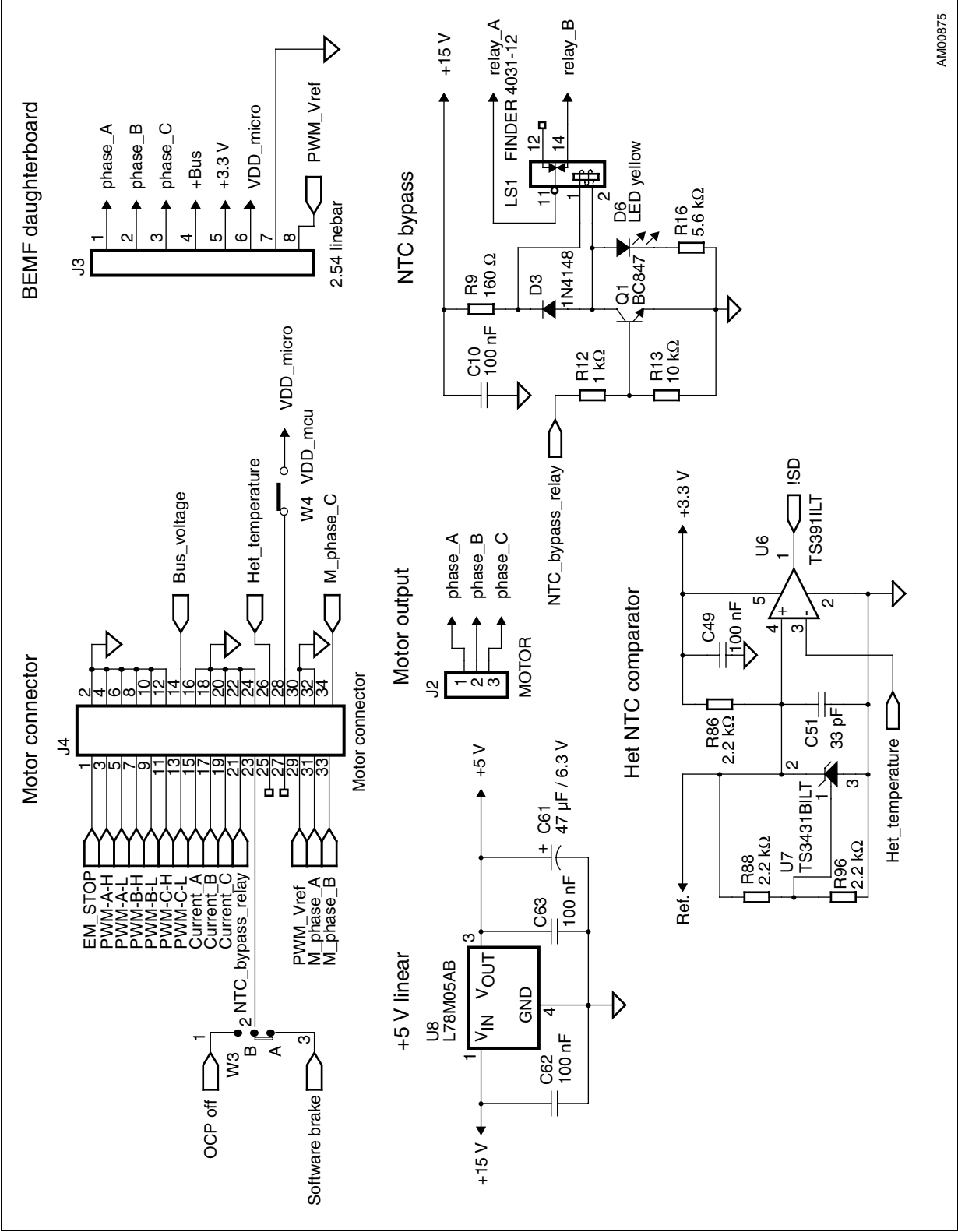


Figure 4. STEVAL-IHM025V1 schematic - part 2



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The schematic diagram illustrates the electrical connections for a motor control system, divided into three main functional blocks: Hall / encoder, Tachometer sensor, and Brake control.

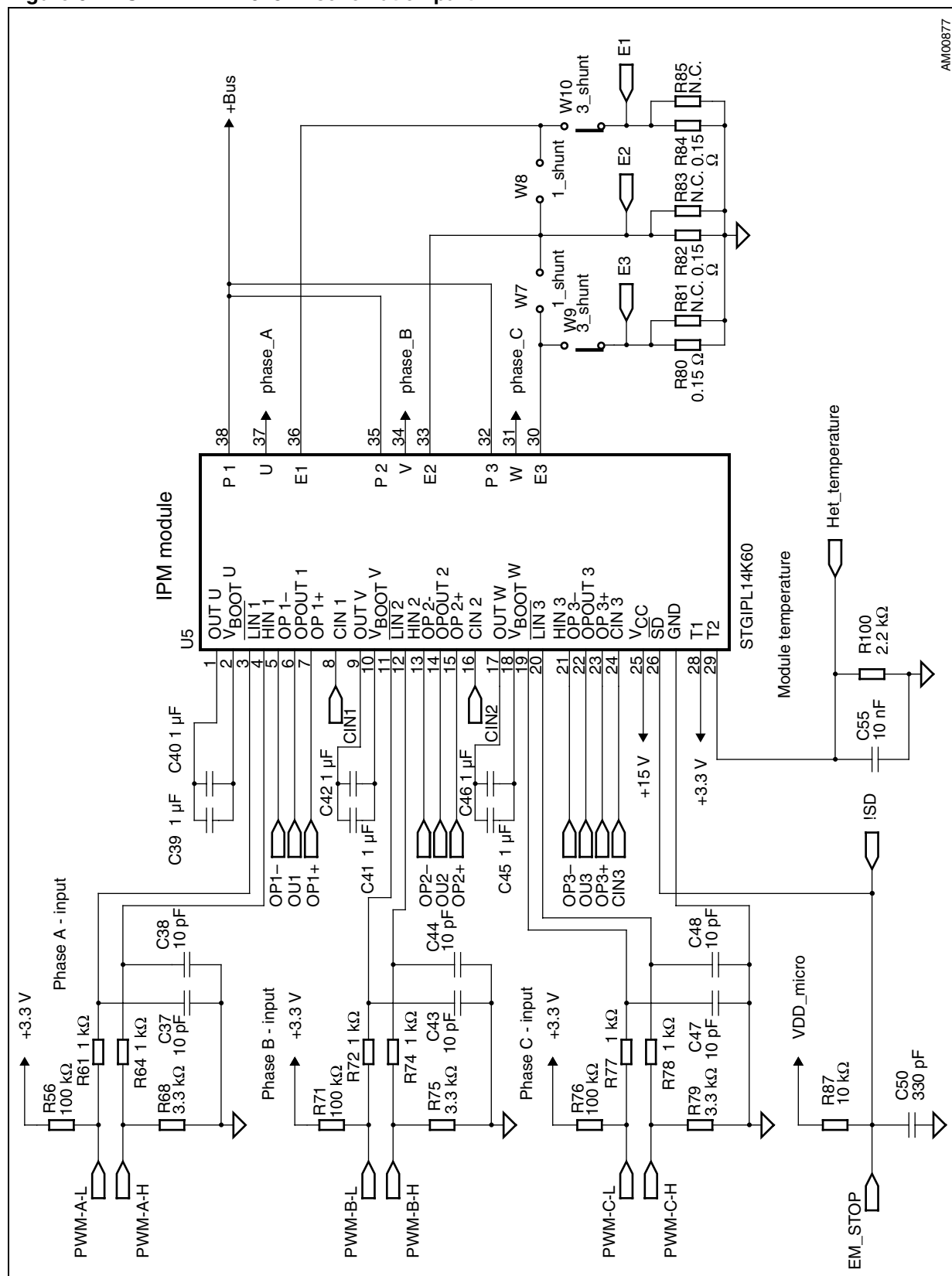
Hall / encoder section: This section interfaces with a Hall effect sensor (U9A, M74HC14RM) and an encoder (J5). The Hall sensor output is connected to the microcontroller's VDD_micro and +5V lines. The encoder output is connected to the microcontroller's VDD_micro and +5V lines. The microcontroller's VDD_micro and +5V lines are connected to the motor's VDD_micro and +5V lines.

Tachometer sensor section: This section interfaces with a tachometer sensor (J7) and a microcontroller (U9B, M74HC14RM). The tachometer output is connected to the microcontroller's VDD_micro and +5V lines. The microcontroller's VDD_micro and +5V lines are connected to the motor's VDD_micro and +5V lines.

Brake control section: This section controls the motor's brake (J6) and a software brake (U4, TS391ILT). The brake control output is connected to the microcontroller's VDD_micro and +5V lines. The software brake output is connected to the microcontroller's VDD_micro and +5V lines.

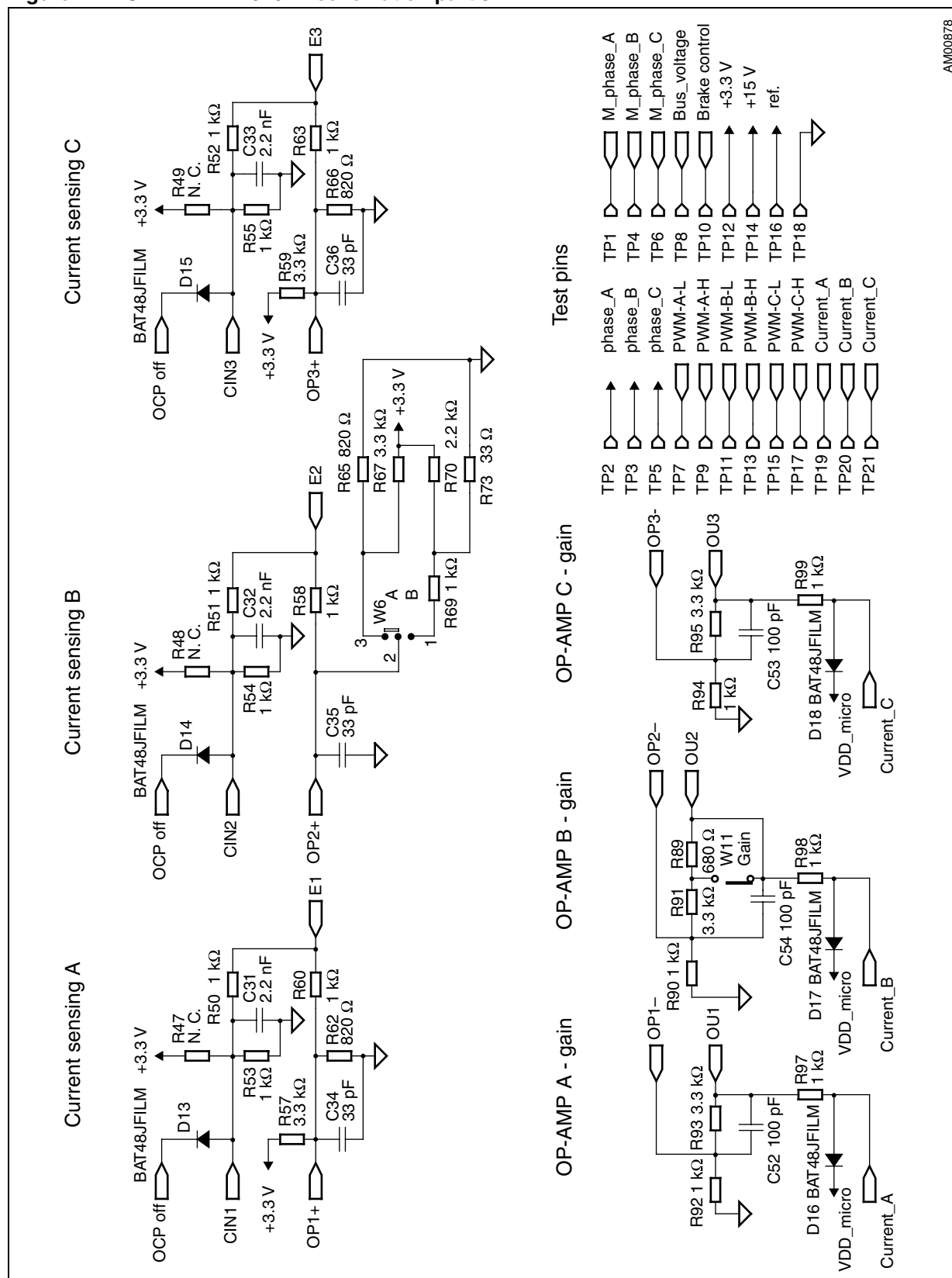
The diagram includes various components such as resistors (R101, R102, R103, R104, R105, R106, R107, R108, R109, R110, R111, R112, R113, R114, R115, R116, R117, R118, R119, R120, R121, R122, R123, R124, R125, R126, R127, R128, R129, R130, R131, R132, R133, R134, R135, R136, R137, R138, R139, R140, R141, R142, R143, R144, R145, R146, R147, R148, R149, R150, R151, R152, R153, R154, R155, R156, R157, R158, R159, R160, R161, R162, R163, R164, R165, R166, R167, R168, R169, R170, R171, R172, R173, R174, R175, R176, R177, R178, R179, R180, R181, R182, R183, R184, R185, R186, R187, R188, R189, R190, R191, R192, R193, R194, R195, R196, R197, R198, R199, R200, R201, R202, R203, R204, R205, R206, R207, R208, R209, R210, R211, R212, R213, R214, R215, R216, R217, R218, R219, R220, R221, R222, R223, R224, R225, R226, R227, R228, R229, R230, R231, R232, R233, R234, R235, R236, R237, R238, R239, R240, R241, R242, R243, R244, R245, R246, R247, R248, R249, R250, R251, R252, R253, R254, R255, R256, R257, R258, R259, R260, R261, R262, R263, R264, R265, R266, R267, R268, R269, R270, R271, R272, R273, R274, R275, R276, R277, R278, R279, R280, R281, R282, R283, R284, R285, R286, R287, R288, R289, R290, R291, R292, R293, R294, R295, R296, R297, R298, R299, R300, R301, R302, R303, R304, R305, R306, R307, R308, R309, R310, R311, R312, R313, R314, R315, R316, R317, R318, R319, R320, R321, R322, R323, R324, R325, R326, R327, R328, R329, R330, R331, R332, R333, R334, R335, R336, R337, R338, R339, R340, R341, R342, R343, R344, R345, R346, R347, R348, R349, R350, R351, R352, R353, R354, R355, R356, R357, R358, R359, R360, R361, R362, R363, R364, R365, R366, R367, R368, R369, R370, R371, R372, R373, R374, R375, R376, R377, R378, R379, R380, R381, R382, R383, R384, R385, R386, R387, R388, R389, R390, R391, R392, R393, R394, R395, R396, R397, R398, R399, R400, R401, R402, R403, R404, R405, R406, R407, R408, R409, R410, R411, R412, R413, R414, R415, R416, R417, R418, R419, R420, R421, R422, R423, R424, R425, R426, R427, R428, R429, R430, R431, R432, R433, R434, R435, R436, R437, R438, R439, R440, R441, R442, R443, R444, R445, R446, R447, R448, R449, R450, R451, R452, R453, R454, R455, R456, R457, R458, R459, R460, R461, R462, R463, R464, R465, R466, R467, R468, R469, R470, R471, R472, R473, R474, R475, R476, R477, R478, R479, R480, R481, R482, R483, R484, R485, R486, R487, R488, R489, R490, R491, R492, R493, R494, R495, R496, R497, R498, R499, R500, R501, R502, R503, R504, R505, R506, R507, R508, R509, R510, R511, R512, R513, R514, R515, R516, R517, R518, R519, R520, R521, R522, R523, R524, R525, R526, R527, R528, R529, R530, R531, R532, R533, R534, R535, R536, R537, R538, R539, R540, R541, R542, R543, R544, R545, R546, R547, R548, R549, R550, R551, R552, R553, R554, R555, R556, R557, R558, R559, R560, R561, R562, R563, R564, R565, R566, R567, R568, R569, R570, R571, R572, R573, R574, R575, R576, R577, R578, R579, R580, R581, R582, R583, R584, R585, R586, R587, R588, R589, R590, R591, R592, R593, R594, R595, R596, R597, R598, R599, R600, R601, R602, R603, R604, R605, R606, R607, R608, R609, R610, R611, R612, R613, R614, R615, R616, R617, R618, R619, R620, R621, R622, R623, R624, R625, R626, R627, R628, R629, R630, R631, R632, R633, R634, R635, R636, R637, R638, R639, R640, R641, R642, R643, R644, R645, R646, R647, R648, R649, R650, R651, R652, R653, R654, R655, R656, R657, R658, R659, R660, R661, R662, R663, R664, R665, R666, R667, R668, R669, R670, R671, R672, R673, R674, R675, R676, R677, R678, R679, R680, R681, R682, R683, R684, R685, R686, R687, R688, R689, R690, R691, R692, R693, R694, R695, R696, R697, R698, R699, R700, R701, R702, R703, R704, R705, R706, R707, R708, R709, R710, R711, R712, R713, R714, R715, R716, R717, R718, R719, R720, R721, R722, R723, R724, R725, R726, R727, R728, R729, R730, R731, R732, R733, R734, R735, R736, R737, R738, R739, R740, R741, R742, R743, R744, R745, R746, R747, R748, R749, R750, R751, R752, R753, R754, R755, R756, R757, R758, R759, R760, R761, R762, R763, R764, R765, R766, R767, R768, R769, R770, R771, R772, R773, R774, R775, R776, R777, R778, R779, R780, R781, R782, R783, R784, R785, R786, R787, R788, R789, R790, R791, R792, R793, R794, R795, R796, R797, R798, R799, R800, R801, R802, R803, R804, R805, R806, R807, R808, R809, R810, R811, R812, R813, R814, R815, R816, R817, R818, R819, R820, R821, R822, R823, R824, R825, R826, R827, R828, R829, R830, R831, R832, R833, R834, R835, R836, R837, R838, R839, R840, R841, R842, R843, R844, R845, R846, R847, R848, R849,

Figure 6. STEVAL-IHM025V1 schematic - part 4



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Figure 7. STEVAL-IHM025V1 schematic - part 5



3.3 Circuit description

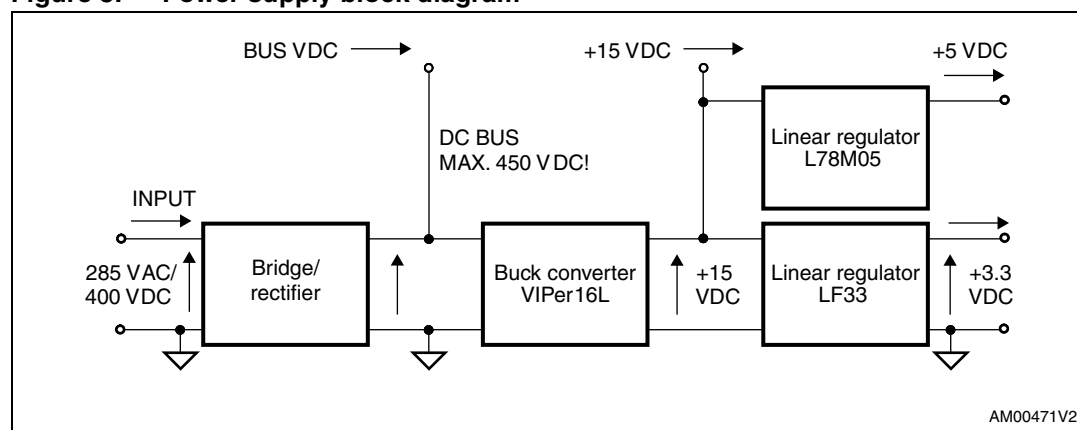
3.3.1 Power supply

The power supply in the STEVAL-IHM025V1 demonstration board is implemented as a wide range converter. The working input voltage range is from 90 VAC or 125 VDC up to 285 VAC or 400 VDC.

The auxiliary power supply for all active components on the demonstration board is implemented with a buck converter based on U6 VIPer16L 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 supplying 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 demonstration board. Please refer to STMicroelectronics' VIPer16LD datasheet for further information.

The presence of a +15 VDC on the board is indicated with red LED D5. [Figure 8](#) below describes the power supply section with a simplified block diagram.

Figure 8. Power supply block diagram



3.3.2 Inrush limitation

The input stage of the demonstration 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 startup phase. The NTC bypass signal is provided from the MCU board through the J4 connector. The yellow LED diode D6 is turned off when the inrush resistor is disabled.

A basic EMI filter based on X2 and Y2 capacitors was implemented on the STEVAL-IHM025V1. 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 final target applications. 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 demonstration board.

3.3.3 Power block based on IGBT module

The IGBT module STGIPL14K60 consists of IGBT power switches, smart drivers, and operational amplifiers. STGPIL14K60 is provided with advanced gate drivers, many features

are available like: integrated op-amp for signal conditioning, integrated comparators for overcurrent or short-circuit protection, and the “SMART SHUTDOWN” function. Please refer to the STGIPL14K60 datasheets for more information.

3.3.4 Brake function

A hardware brake feature is implemented on the STEVAL-IHM025V1 demonstration board. This feature connects the external dummy load applied to the J6 connector to the bus, to eliminate overvoltage generated while the motor acts as a generator. Voltage on the bus is sensed through a voltage divider net, with R32, R33 and R42 resistors, and it is compared to the voltage reference built around the precise voltage reference U3. The brake dummy load is switched on when voltage on the bus reaches 445 VDC and is switched off when the voltage falls below 420 VDC. The brake function can be activated by the microcontroller thanks to the motor-control connector (please set the W3 jumper in position “A”). The brake threshold levels can be modified by calculating R32, R33, R42 and R45 new values.

3.3.5 Overcurrent protection

Hardware overcurrent protection (OCP) is implemented on the board. STGIPL14K60 integrates three internal comparators. Thanks to the internal connection between the comparator output and shutdown block (see [Figure 9](#)), the intervention time of overcurrent protection is extremely low, ranging slightly above 200 ns (Smart Shutdown).

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

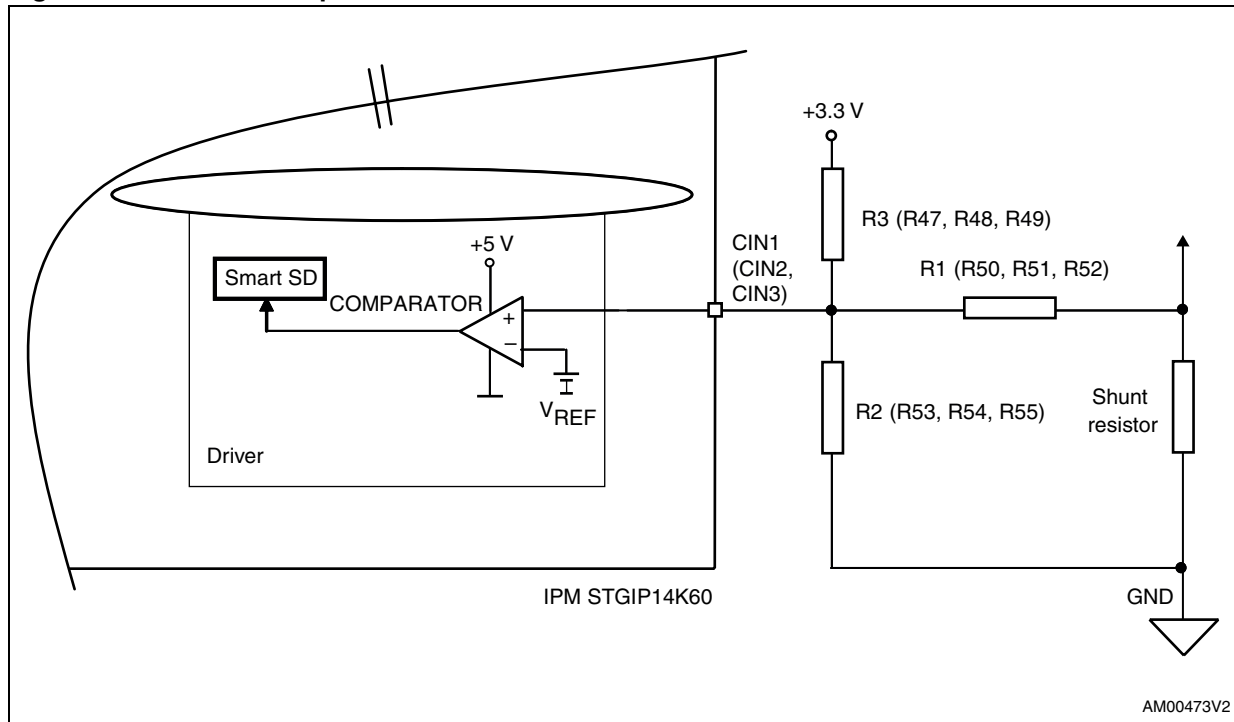
Equation 1

$$I_{\text{SHUNT_MAX}} = \frac{V_{\text{REF}}}{R_{\text{SHUNT}}} \times \left(1 + \frac{R1}{R2}\right)$$

Note: R3 is not connected on the STEVAL-IHM025V1.

With the default values this gives:

- $I_{\text{SHUNT_MAX}} = 7 \text{ A}$

Figure 9. Overcurrent protection

Overcurrent protection can be disabled if the W3 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 is possible to short the motor phases, preventing the motor current from flowing through the bulk capacitors.

The current into the motor phases is normally limited by the motor phase impedance but during the short-circuit transient, a high current can flow through the switches for a few ms. In order to avoid false triggering it may be necessary to deactivate the OCP with this jumper configuration.

3.3.6 Current sensing amplifying network

Three-shunt current reading configuration

Details of the three-shunt current-sensing reading configuration are shown in [Figure 10](#). 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 follower mode: its gain is set by resistor r and R :

Equation 2

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

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

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

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

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

Total gain of the circuit including resistors' divider is equal to:

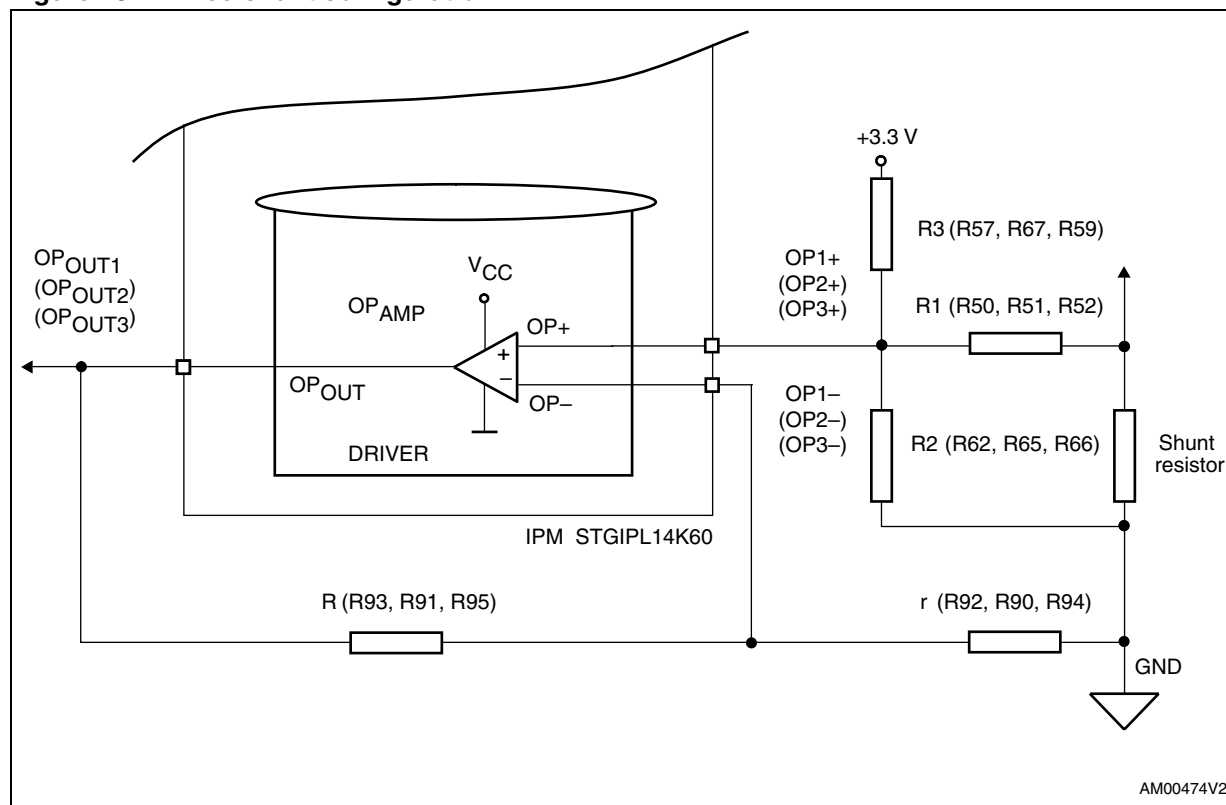
Equation 4

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

With the default values this gives:

- $V_{BIAS} = 1.7 \text{ V}$
- $G = 4.3$
- $G_{TOT} = 1.7$
- Maximum current amplifiable without distortion is 6.5 A.

Figure 10. Three-shunt configuration



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. Moreover, 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 11](#). 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 resistor r and R:

Equation 5

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

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

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

$$V_{BIAS} = \frac{3.3 \times \frac{R1}{R1 + R2}}{\left(\frac{1}{R3} + \frac{1}{R1 + R2} + \frac{1}{R4} \right) \times R4} \times G$$

$$V_{SIGN} = \frac{I \times R_{SHUNT} \times [R2 \times (R3 + R4) + R3 \times R4]}{(R1 + R2) \times (R3 + R4) + R3 \times R4} \times G$$

Total gain of the circuit with the resistors' divider is equal to:

Equation 7

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

With the default values this gives:

- $V_{BIAS} = 0.12 \text{ V}$
- $G = 4.98$
- $G_{TOT} = 2.53$
- Maximum current amplifiable without distortion is 6.5 A.

Figure 11. Six-step current sensing configuration

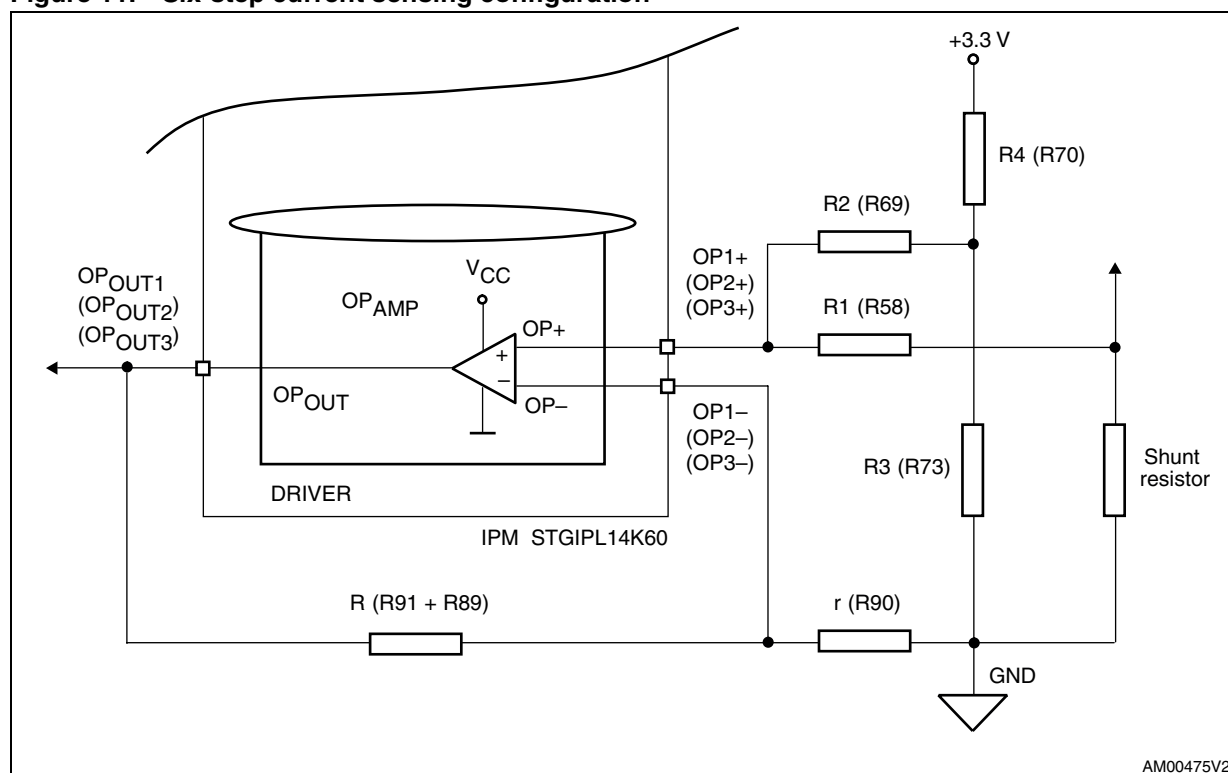


Table 1. Current reading configuration - gain settings

Jumper	Gain configuration	
	Six-step current sensing	Three-shunt
W11	Not present	Present
W6	B position	A position

3.3.7 The tachometer and hall/encoder inputs

Both the tachometer and hall/encoder inputs have been implemented on the board. In the case of using a hall or encoder sensor, the W2 jumper must be connected and the W5 jumper disconnected. The W12 jumper set in position A allows to supply any connected hall sensor with the same supply voltage of MCU (+3.3 VDC or +5 VDC depend on the W1 jumper). Setting the W12 jumper to position B supplies the hall sensor directly with +5 VDC, which is the most common voltage for a hall sensor. As a voltage level shifter between +5 VDC hall sensor and +3.3 VDC, control logic uses features built around the U9 Hex Schmitt inverter. In the case of using a tachometer, the W2 jumper must be disconnected and the W5 jumper connected.

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

3.3.8 Temperature feedback and overtemperature protection (OTP)

Hardware overtemperature protection is also implemented on the STEVAL-IHM025V1 demonstration board. This feature fully protects the IPM module against damage when the temperature on the junction on the IPM overruns a defined value. The temperature is sensed through an NTC resistor which is integrated into the IPM. The measured signal is fed through the J4 motor connector to the MCU control unit and can be read with an A-D converter. The signal is also fed to the U6 comparator where it is compared with a 2.5 V reference voltage which is built around U7 precision reference TS3431. The output signal of the U6 comparator is fed into the SD pin of the IPM to stop the commutation of the connected motor. With the value of the integrated NTC resistor inside the IPM and R100 resistor equal to 2.2k Ω the shutdown temperature is roughly 85 °C.

4 Hardware setting of the STEVAL-IHM025V1

The STEVAL-IHM025V1 demonstration board can be driven through the J4 motor connector by various control units released by STMicroelectronics. The demonstration board is suitable for field oriented control as well as for tachometer or hall sensor closed-loop control. The STEVAL-IHM025V1 demonstration board ideally fits with STMicroelectronics' released STM3210B-EVAL board based on the STM32 MCU family as the control unit for FOC-driving algorithms.

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

To drive any motor, the user must ensure that:

- The motor control demonstration board is driven by a control board that provides the six output signals required to drive the 3-phase power stage
- The motor is connected to the J2 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 J7
- If using a dissipative hardware brake connection to a related dummy load, it is connected to connector J6.

[Table 2](#) below shows the jumper settings for any motors. Please confirm that the demonstration board input voltage (mains voltage) is in the range of 125 VDC to 400 VDC or 90 VAC to 285 VAC.

Table 2. Jumper settings for PMSM or generic AC motor - six-step

Jumper	Settings for six-step current control - single shunt configuration	
	HV PMSM motor	Generic AC motor with tachometer
W1	A position for 3.3 V supplied MCU	A position for 3.3 V supplied MCU
W2	Present	Not present
W3	Software brake / OCP disabled	Software brake / OCP disabled
W4	Present in case of need V_{DD} for MCU	Present in case of need V_{DD} for MCU
W5	Not present	Present
W6	B position	B position
W7	Present	Present
W8	Present	Present
W9	Not present	Not present
W10	Not present	Not present
W11	Not present	Not present
W12	Depends on hall supply voltage	Depends on hall supply voltage

4.2 Hardware settings with three-shunt configuration

To drive any motor, the user must ensure that:

- The motor control demonstration board is driven by a control board that provides the six output signals required to drive the 3-phase power stage
- The motor is connected to the J2 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 J7
- If using a dissipative hardware brake connection to a related dummy load, it is connected to the J6 connector.

[Table 3](#) below shows the jumper settings for any motors. Please confirm that the demonstration board input voltage (mains 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 - three shunt

Jumper	Settings with three-shunt configuration	
	HV PMSM motor	Generic AC motor with tachometer
W1	A position for 3.3 V supplied MCU	A position for 3.3 V supplied MCU
W2	Present	Not present
W3	Software brake / OCP disabled	Software brake / OCP disabled
W4	Present in case of need V_{DD} for MCU	Present in case of need V_{DD} for MCU
W5	Not present	Present
W6	A position	A position
W7	Not present	Not present
W8	Not present	Not present
W9	Present	Present
W10	Present	Present
W11	Present	Present
W12	Depends on hall supply voltage	Depends on hall supply voltage

5 Description of jumpers, test pins and connectors

The following tables give a detailed description of the jumpers, test pins and the pinout of the connectors used. [Table 4](#) gives a detailed description of the jumpers. [Table 5](#) gives a detailed description of the connectors and [Table 6](#) describes all the test pins placed on the board.

Table 4. Jumper description

Jumper	Selection	Description
W1	A position	Supplies peripheral on the board with 3.3 V
	B position	Supplies peripheral on the board with 5 V
W2	Present	Connects H1 pin of encoder/hall sensor connector to measure phase A
	Not present	Disconnects H1 pin of encoder/hall sensor connector to measure phase A
W3	A position	Software brake feature applied
	B position	Overcurrent protection can be disabled with software
W4	Present	Supplies direct driving board through the J4 connector (max. current 50 mA)
	Not present	Separated voltage
W5	Present	Connects tachometer signal to measure phase A
	Not present	Disconnects tachometer signal to measure phase A
W6	A position	Sets the gain of phase B current op. amplifier for three-shunt configuration
	B position	Sets the gain of phase B current op. amplifier for single-shunt configuration
W7	Present	Shorts W and V emitters legs - setting for single-shunt configuration
	Not present	Setting for three-shunt configuration
W8	Present	Shorts V and U emitter legs - setting for single-shunt configuration
	Not present	Setting for three shunt configuration
W9	Present	Applies shunt resistor to W phase emitter leg
	Not present	Setting for single shunt configuration
W10	Present	Applies shunt resistor to U phase emitter leg
	Not present	Setting for single shunt configuration
W11	Present	Sets the gain of phase B current op. amplifier for three-shunt configuration
	Not present	Sets the gain of phase B current op. amplifier for single-shunt configuration
W12	A position	Sets the same supply voltage for the hall sensor as for the rest of peripheral
	B position	Sets 5 VDC supply voltage for hall sensor

Table 5. Connector pinout description

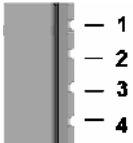
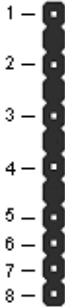
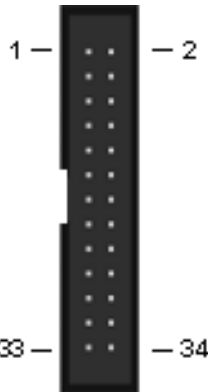
Name	Reference	Description / pinout
J1		Supply connector 1 - L- phase 2 - N- neutral 3 - PE- protected earth 4 - PE- protected earth
J2		Motor connector A - phase A B - phase B C - phase C
J3		BEMF daughterboard connector 1 - phase A 2 - phase B 3 - phase C 4 - bus voltage 5 - 3.3 VDC 6 - V _{DD_micro} 7 - GND 8 - PWM V _{REF}
J4		Motor control connector 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

Table 5. Connector pinout description (continued)

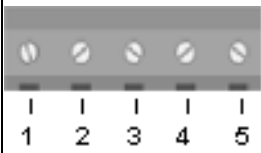
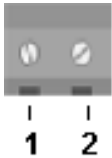
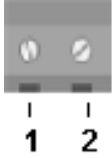
Name	Reference	Description / pinout
J5		Hall sensor/ encoder input connector 1 - hall sensor input 1/encoder A+ 1 - hall sensor input 2/encoder B+ 1 - hall sensor input 3/encoder Z+ 4 - 5 VDC 5 - GND
J6		Dissipative brake 1 - bus voltage 2 - open collector
J7		Tachometer input connector for AC motor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

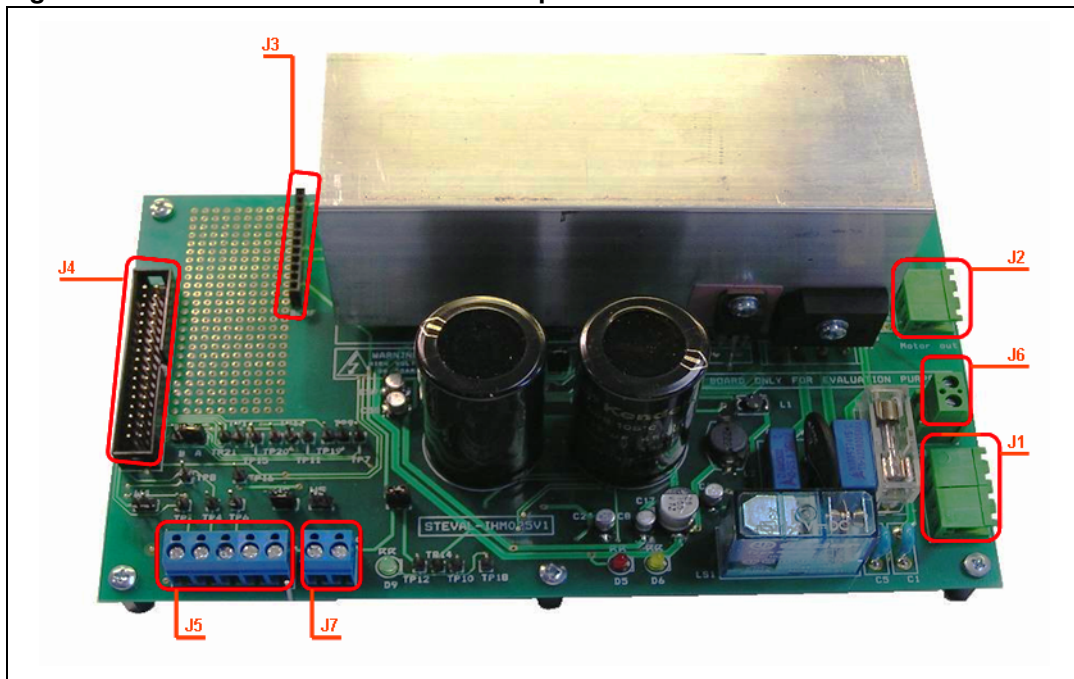
Table 6. Testing pins description

Number	Description
TP1	Sensed tachometer/encoder/hall signal A
TP2	Output phase A
TP3	Output phase B
TP4	Sensed encoder/hall signal B
TP5	Output phase C
TP6	Sensed encoder/hall signal Z
TP7	PWM - phase A - low-side
TP8	Voltage on bus divider - bus voltage information
TP9	PWM - phase A - high-side
TP10	Brake status - brake active in low state
TP11	PWM - phase B - low-side
TP12	3.3 VDC
TP13	PWM - phase B - high-side
TP14	15 VDC
TP15	PWM - phase C - low-side
TP16	Reference voltage 2.5 V for overtemperature protection
TP17	PWM - phase C - high-side
TP18	GND
TP19	Current in phase A
TP20	Current in phase B
TP21	Current in phase C

6 Connector placement

A basic description of the placement of all connectors on the board is visible in [Figure 9](#).

Figure 12. STEVAL-IHM025V1 connector placement



7 Bill of materials

A list of components used to build the demonstration board is shown in [Table 7](#). The majority of the active components used are available from STMicroelectronics.

Table 7. Bill of materials

Reference	Value / generic part number	Package / class	Manufacturer
C1,C5	2.2 nF / Y1	Y1 safety CAP - 2.2 nF	Murata Manufacturing Co., Ltd.
C2, C3	330 μ F / 450 V	Elyt. capacitor, RM10 mm, 30 x 50, 105 °C	EPCOS B43504-A5337-M
C14	150 nF / X2	Foil X2 capacitor, RM 15 mm	EPCOS B32922C3154M
C15	1 μ F / 50 V	Elyt. capacitor, SMD 4 x 4	any
C17	100 μ F / 25 V	Elyt. capacitor, SMD 8 x 8	any
C6,C7,C10,C11,C16,C18,C23,C25,C26,C27,C49,C56,C57,C60,C62,C63	100 nF	Capacitor, SMD 0805	any (AVX, etc.)
C19,C20,C21,C37,C38,C43,C44,C47,C48	10 pF	Capacitor, SMD 0805	AVX
C24	4.7 μ F / 25 V	Elyt. capacitor, SMD 4 x 4	any
C28,C31,C32,C33	2.2 nF	Capacitor, SMD 0805	any (AVX, etc.)
C22	470 pF	Capacitor, SMD 0805	any (AVX, etc.)
C29	4.7 nF	Capacitor, SMD 0805	any (AVX, etc.)
C59	2.2 μ F / 35 V	Elyt. capacitor, SMD 4 x 4	any
C13	220 nF / 16 V	Capacitor, SMD 0805	any (AVX, etc.)
C39,C40,C41,C42,C45,C46	1 μ F / 50 V	Capacitor, SMD 1206; 50 V	AVX
C30,C52,C53,C54	100 pF	Capacitor, SMD 0805	any (AVX, etc.)
C4	330 nF / X2	Foil X2 capacitor, RM 15 mm	EPCOS B32922C3334K
C34,C35,C36,C51	33 pF	Capacitor, SMD 0805	any (AVX, etc.)
C50	330 pF	Capacitor, SMD 0805	any (AVX, etc.)
C8, C58	22 μ F / 6.3 V	Elyt. capacitor, SMD 4 x 4	any
C9,C55	10 nF	Capacitor, SMD 0805	any (AVX, etc.)
R22	15 k Ω	Resistor, SMD 0805, 1%	Vishay™
R31,R46,R56,R71,R76	100 k Ω	Resistor, SMD 0805, 1%	Vishay
VR1	10 Ω	NTC	EPCOS B57364S 100 m
R1,R3,R6	100 k Ω	Resistor, SMD 1206	Vishay

Table 7. Bill of materials (continued)

Reference	Value / generic part number	Package / class	Manufacturer
R11	13 k Ω	Resistor, SMD 0805, 1%	Vishay
C12	N.C.		
R9	160 Ω	Resistor, SMD 1206	Vishay
R17,R18,R19	4.7 k Ω	Resistor, SMD 0805	Vishay
R27	910 Ω	Resistor, SMD 0805, 1%	Vishay
R29,R41	220 Ω	Resistor, SMD 0805	Vishay
R23,R45	6.8 k Ω	Resistor, SMD 0805, 1%	Vishay
R14,R25,R47,R48,R49,R81, R83,R85	N.C.		
R2,R4,R32,R33	470 k Ω	Resistor, SMD 1206, 1%	Vishay
R13,R21,R26,R30,R37,R44, R87	10 k Ω	Resistor, SMD 0805, 1%	Vishay
R34	560 Ω	Resistor, SMD 0805, 1%	Vishay
R15,R16,R20,R24	5.6 k Ω	Resistor, SMD 0805, 1%	Vishay
R61,R64,R72,R74,R77,R78, R90,R92,R94	1 k Ω	Resistor, SMD 0805, 1%	Vishay
R38,R70,R86,R88,R96,R100	2.2 k Ω	Resistor, SMD 0805, 1%	Vishay
R40	100 Ω	Resistor, SMD 0805	Vishay
R35,R42	27 k Ω	Resistor, SMD 0805, 1%	Vishay
R5,R10	120 Ω	Resistor, SMD 0805, 1%	Vishay
R57,R59,R67,R68,R75,R79, R91,R93,R95	3.3 k Ω	Resistor, SMD 0805, 1%	Vishay
R62,R65,R66	820 Ω	Resistor, SMD 0805, 1%	Vishay
R80,R82,R84	0.15 Ω	Resistor, SMD 2512, 1%, 2 W	Vishay
R12,R28,R36,R50,R51,R52, R53,R54,R55,R58,R60,R63, R69,R97,R98,R99	1 k Ω	Resistor, SMD 0805, 1%	Vishay
R89	680 Ω	Resistor, SMD 0805, 1%	Vishay
R7,R43	8.2 k Ω	Resistor, SMD 0805, 1%	Vishay
R8	51 k Ω	Resistor, SMD 0805, 1%	Vishay
R73	33 Ω	Resistor, SMD 0805, 1%	Vishay
R39	220 k Ω	Resistor, SMD 0805, 1%	Vishay
R101,R102, R103,R104,R105,R106	4.7 k Ω	Resistor, SMD 0805	Vishay
L1	47 μ H	SMD choke, 0.5 A	Würth Elektronik 74455147

Table 7. Bill of materials (continued)

Reference	Value / generic part number	Package / class	Manufacturer
L2	2.2 mH	SMD choke, 0.25 A	Würth Elektronik 74456322
D1	KBU6K	Diode bridge, 250 VAC, 8 A	Vishay
D3	1N4148	Universal diode, SMD, DO-80	
D2,D11,D12,D13,D14,D15,D16,D17,D18	BAT48JFILM	Diode, SMD, SOD-323	STMicroelectronics
D10	BZX84B13V	Zener diode, SOT23, 13 V	NXP
D9	LED green	Universal LED 3 mm, 2 mA	Agilent Technologies
D6	LED yellow	Universal LED 3 mm, 2 mA	Agilent Technologies
D4,D7	STTH1L06A	HV diode, SMA	STMicroelectronics
D5	LED red	Universal LED 3 mm, 2 mA	Agilent
D8	BZV55C18SMD	Zener diode, SOD80, 18 V	Vishay
Q1,Q4,Q5,Q6,Q7,Q8,Q9,Q10,Q11,Q12	BC847A	NPN transistor, SOT23	FAIRCHILD
Q3	STGP10NC60KD	N-channel IGBT, TO220	STMicroelectronics
Q2	BC857B	PNP transistor, SOT23	FAIRCHILD
F1	Holder	Fuse holder 5 x 20 mm, KS21 SW	SCHURTER
F1	6.25 A	Fuse 6.25 A slow, FST06.3, 5 x 20 mm	
LS1	FINDER 4031-12	Relay 12 VDC	Finder
U1	LF33ABDT-TR	Linear regulator 3.3 V	STMicroelectronics
U2	VIPer16LD	Smart PWM driver, SO-16	STMicroelectronics
U4,U6	TS391ILT	Voltage comparator, SOT23-5	STMicroelectronics
U5	STGIPL14K60	IPM with IGBT; SDIP 38L	STMicroelectronics
U3,U7	TS3431BILT	Voltage reference, SOT 23	STMicroelectronics
U8	L78M05ABDT-TR	Voltage regulator, DPAK	STMicroelectronics
U9	M74HC14RM13TR	Logic IO, SO-14	STMicroelectronics
TP2,TP3,TP5	PCB terminal 1 mm	Not assembled	
TP1,TP4,TP6-TP21	PCB terminal 1 mm	Test pin	
J1	Connector 4P	Connector RM 5 mm, 4-pole male and female	
J2	Connector 3P	Connector RM5 mm, 3-pole male and female	
J7	Con. 5 mm, 2P	Connector RM 5 mm, 2-pole, screw	ARK
J5	Con. 5 mm, 2P + 3P	Connector RM 5 mm, 2-pole and 3-pole, screw	ARK
J4	MLW34G	MLW connector 34 pins	ARK

Table 7. Bill of materials (continued)

Reference	Value / generic part number	Package / class	Manufacturer
J6	Con. 5 mm, 2P	Connector RM 5 mm, 2-pole, screw	ARK
J3	BL815G	12-pin connector RM 2.54 mm	
W1	Jumper 2.54	Three pins of pin header + jumper in position A	
W2	Jumper 2.54	Two pins of pin header + jumper	
W3	Jumper 2.54	Three pins of pin header + jumper in position A	
W4	Jumper 2.54	Two pins of pin header	
W5	Jumper 2.54	Two pins of pin header	
W6	Jumper 2.54	Three pins of pin header + jumper in position A	
W7	Wire jumper	Not assembled	
W8	Wire jumper	Not assembled	
W9	Wire jumper	Wire	
W10	Wire jumper	Wire	
W11	Jumper 2.54	Two pins of pin header + jumper	
W12	Jumper 2.55	Three pins of pin header + jumper in position A	
Het 1	Heatsink	120 mm of AL profile 8284	PADA Engineering

8 PCB layout

For this application a standard, double-layer, coppered PCB with a ~45 µm copper thickness was selected. The PCB material is FR-4.

The dimensions of the board are:

Length: 190 mm

Width: 110 mm

PCB thickness: 1.55 mm

Figure 13. Copper tracks - top side

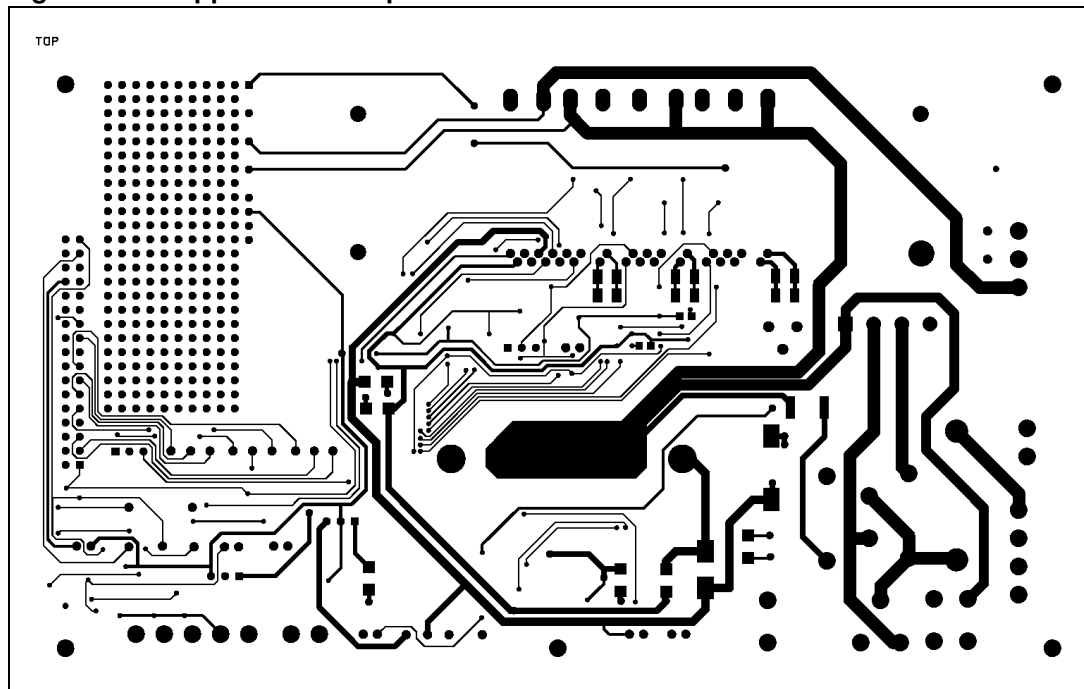


Figure 14. Copper tracks - bottom side

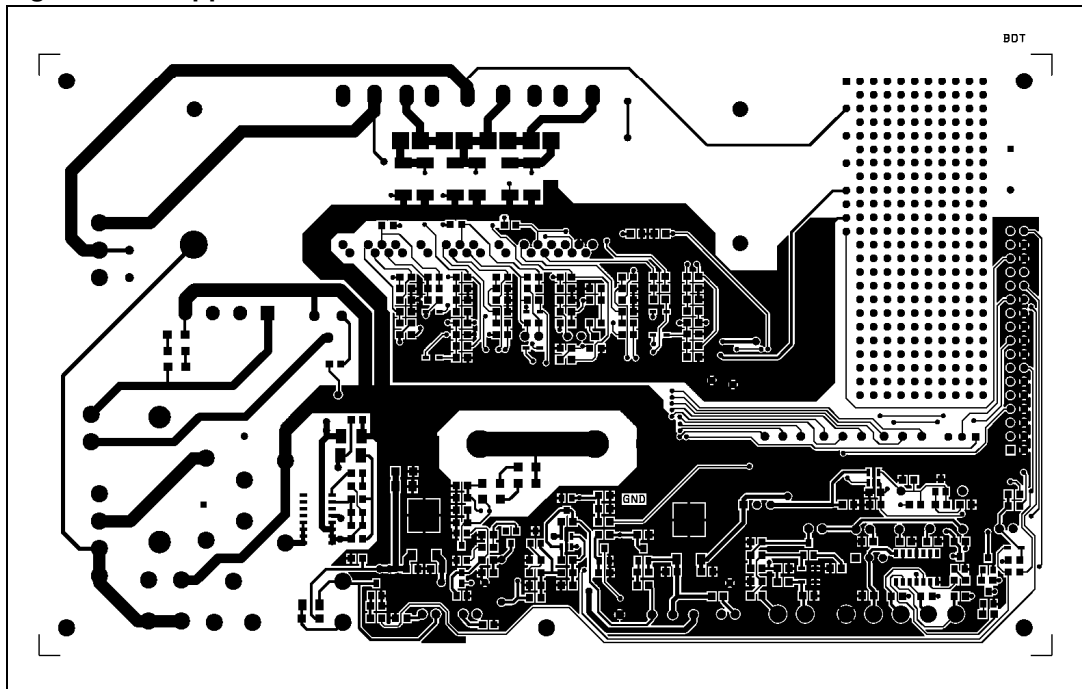


Figure 15. Silk screen - top side

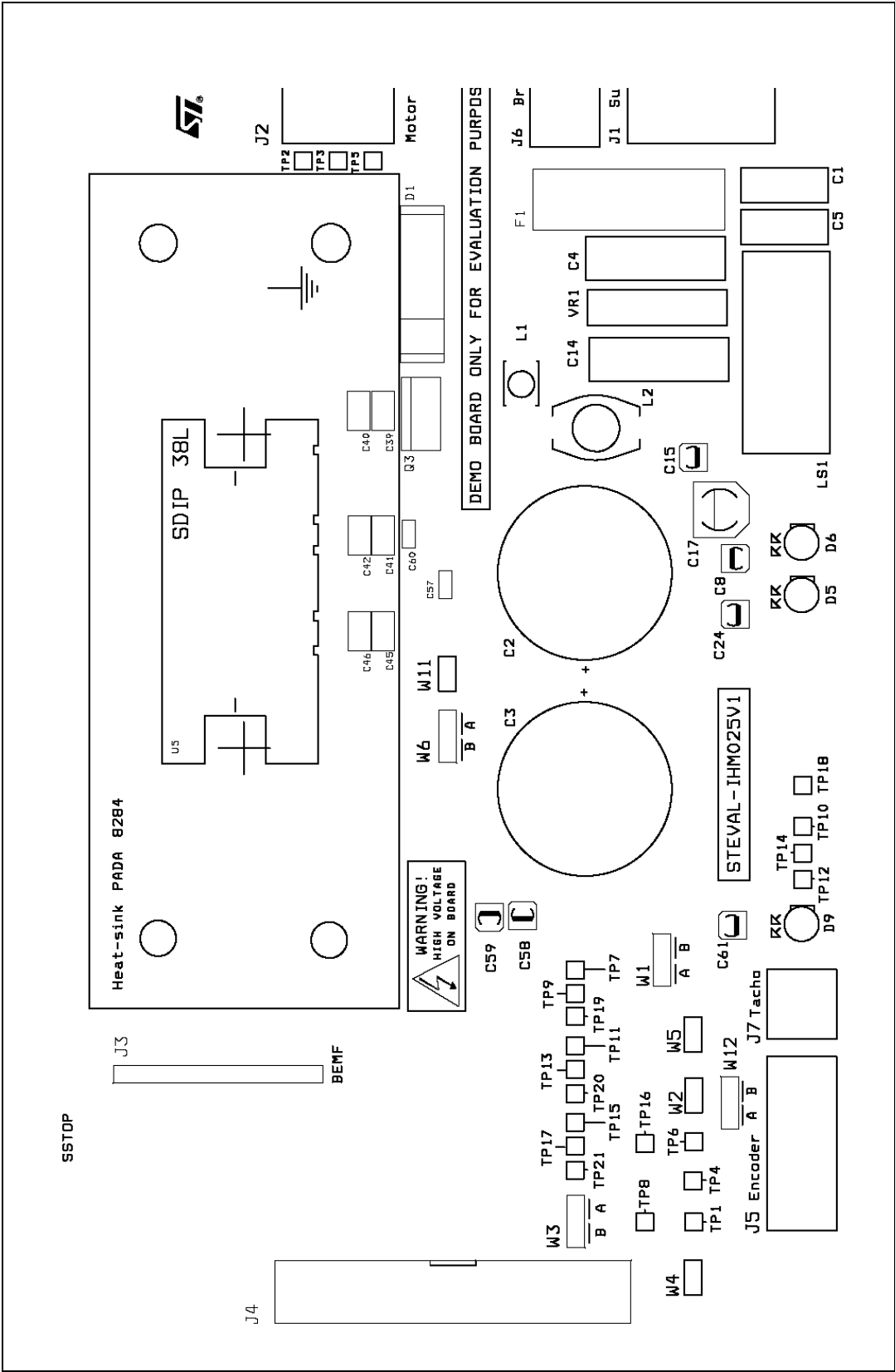
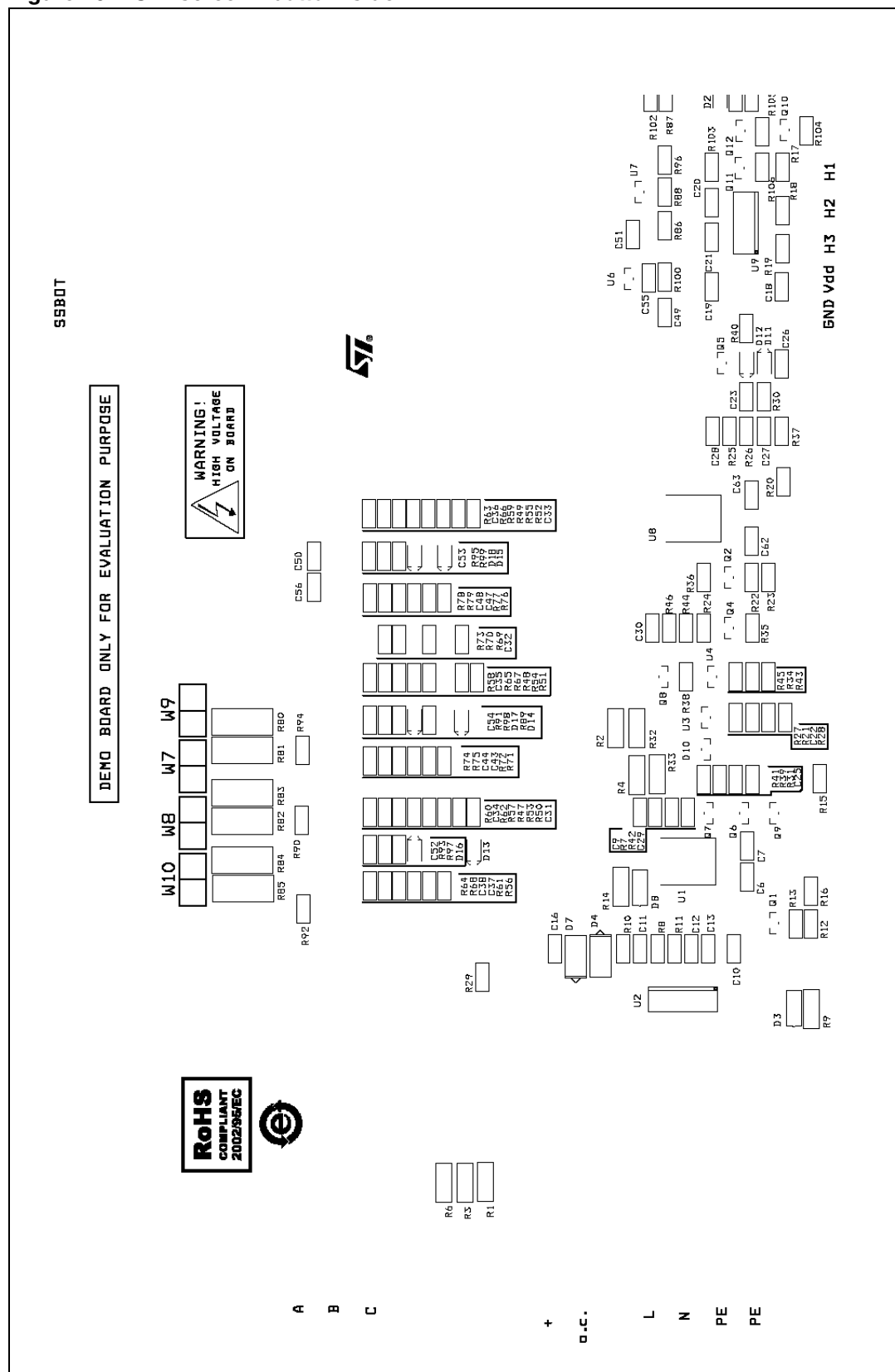


Figure 16. Silk screen - bottom side



9 Ordering information

The demonstration board is available through the standard ordering system, the order code is: STEVAL-IHM025V1. 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 the STEVAL-IHM025V1 with STM32 FOC firmware library

STM32 FOC firmware library v2.0 is a firmware library running on the STM3210B-MCKIT which allows the performing of the FOC of a PMSM in configuration with and without sensors.

This section describes the modifications to be applied to the STM32 FOC firmware library v2.0 in order to make the firmware compatible with the STEVAL-IHM025V1.

10.1 Environmental considerations

Warning: The STEVAL-IHM025V1 demonstration 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 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, TRIAC + Microcontroller: safety precautions for development tools,” application note. (Although this Application Note was written for 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-IHM025V1 together with the STM32 FOC firmware library, the following items are required:

- The board: STEVAL-IHM025V1
- High voltage insulated AC power supply up to 230 VAC
- J-link programmer (not included in the package)
- J-link insulating board (not included in the package)
- 3-phase brushless motor with permanent magnet rotor or a generic 3-phase induction motor (not included in the package)
- Insulated oscilloscope (as needed)
- Insulated multimeter (as needed).

10.3 Software requirements

To customize, compile, and download the STM32 FOC firmware library v2.0 motor control firmware, the IAR tool “EWARM v5.30” must be installed. The free 32 kB limited version (referenced as “IAR KickStart Kit™” version) is available for download at:

<http://supp.iar.com/Download/SW/?item=EWARM-KS32>

10.4 Software modifications

Apart from the parameters header file which can be edited by using the 'FOCGUI application' downloadable from:

<http://www.st.com/mcu/modules.php?name=mcu&file=familiesdocs&fam=110&doc=59>

the STM32 FOC firmware library v2.0 was designed in order to be compatible with the L6386 drivers. In order to make the firmware compatible with IPM STGIPL14K60, the polarity of the PWM driving the low-side transistors must be changed.

To achieve this task, perform the following steps:

1. In 'stm32f10x_svpwm_3shunt.c' substitute line 177 with:
`TIM1_OCInitStructure.TIM_OCNPolarity = TIM_OCNPolarity_Low;`
2. In 'stm32f10x_svpwm_1shunt.c' substitute line 311 with:
`TIM1_OCInitStructure.TIM_OCNPolarity = TIM_OCNPolarity_Low;`
3. In 'stm32f10x_svpwm_3shunt.c' substitute line 88 with:
`#define LOW_SIDE_POLARITY TIM_OCIdleState_Set`
4. In 'stm32f10x_svpwm_1shunt.c' substitute line 66 with:
`#define LOW_SIDE_POLARITY TIM_OCIdleState_Set`
5. In 'MC_MotorControl_Layer.c', substitute line 49 with:
`#define NTC_THRESHOLD 25000`

Note: This sets the overtemperature protection to about 85 °C.

11 Conclusion

This document describes the 1 kW 3-phase motor control STEVAL-IHM025V1 demonstration board based on IPM as a universal fully-evaluated platform.

12 References

1. STMicroelectronics STGIPL14K60 device datasheet - see www.st.com/stonline/products/literature/ds/15589/stgipl14k60.pdf
2. STMicroelectronics VIPer16 device datasheet - see www.st.com/stonline/products/literature/ds/15232.pdf
3. STMicroelectronics STGP10NC60KD device datasheet - see www.st.com/stonline/products/literature/ds/11423/stgp10nc60kd.pdf
4. STMicroelectronics user manual UM0379: "STM3210B-MCKIT and STR750-MCKIT 3-phase motor control power stage" - see www.st.com/stonline/products/literature/um/13031.pdf
5. STMicroelectronics user manual UM0580: "100W 3-phase inverter featuring L6390 and STD5NK52ZD for vector control STEVAL-IHM023V1" - see www.st.com/stonline/products/literature/um/14958.pdf
6. STMicroelectronics user manual UM0723: "1kW 3-phase motor control demonstration board featuring L6390 drivers and STGP10NC60KD IGBT" - see www.st.com/stonline/products/literature/um/15870.pdf

13 Revision history

Table 8. Document revision history

Date	Revision	Changes
25-May-2010	1	Initial release.

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