

# 1500 W motor control power board based on STIB1560DM2T-L SLLIMM™ 2nd series MOSFET IPM

## Introduction

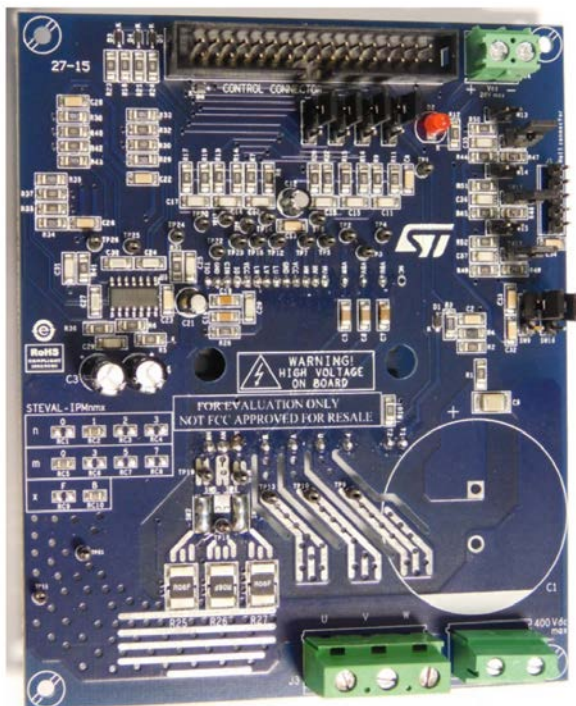
The **STEVAL-IPMM15B** is a compact motor drive power board equipped with SLLIMM™ (small low-loss intelligent molded module) 2nd series based on n-channel power MOSFET MDmesh™ DM2 fast-recovery diode (**STIB1560DM2T-L**). It provides an affordable and easy-to-use solution for driving high power motors for a wide range of applications such as power white goods, air conditioning, compressors, power fans, high-end power tools and 3-phase inverters for motor drives in general. The IPM itself consists of MOSFETs and a wide range of features like undervoltage lockout, smart shutdown, embedded temperature sensor and NTC, and overcurrent protection.

The main characteristics of this evaluation board are small size, minimal BOM and high efficiency. It consists of an interface circuit (BUS and VCC connectors), bootstrap capacitors, snubber capacitor, hardware short-circuit protection, fault event and temperature monitoring. In order to increase the flexibility, it is designed to work in single- or three-shunt configuration and with double current sensing options such as using three dedicated onboard op-amps, or op-amps embedded in the MCU. The Hall/ Encoder part completes the circuit.

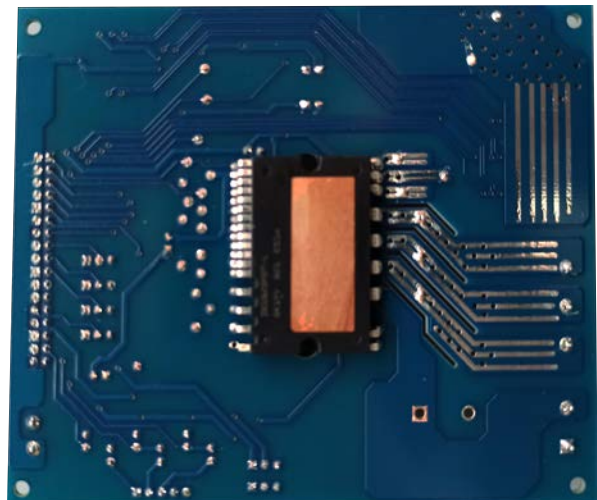
Thanks to these advanced characteristics, the system has been specifically designed to achieve fast and accurate current feedback conditioning, satisfying the typical requirements for field-oriented control (FOC).

The **STEVAL-IPMM15B** is compatible with ST's STM32-based control board, enabling designers to build a complete platform for motor control.

**Figure 1. SLIMM 2nd serie motor control internal demo board (top view)**



**Figure 2. SLIMM 2nd serie motor control internal demo board (bottom view)**



**Note:** These pictures are indicative of the whole board family.

## 1 Key features

- Input voltage: 125 - 400 VDC
- Nominal power: up to 1500 W
  - Allowable maximum power is related to the application conditions and cooling system
- Nominal current: up to 6 A<sub>rms</sub>
- Input auxiliary voltage: up to 20 V DC
- Single- or three-shunt resistors for current sensing (with sensing network)
- Two options for current sensing: dedicated op-amps or through MCU
- Overcurrent hardware protection
- IPM temperature monitoring and protection
- Hall sensor or encoder input
- MOSFET intelligent power module:
  - SLLIMM™ 2nd series IPM (STIB1560DM2T-L - DBC package)
- Motor control connector (32-pin) to interface with ST MCU boards
- Universal conception for further evaluation with breadboard and testing pins
- Very compact size
- WEEE compliant
- RoHS compliant

## 2 Circuit schematics

The full schematics for the SLLIMM™ 2nd series card for [STIB1560DM2T-L](#) IPM products is shown below. This card consists of an interface circuit (BUS and  $V_{CC}$  connectors), bootstrap capacitors, snubber capacitor, shortcircuit protection, fault output circuit, temperature monitoring, single-/three-shunt resistors and filters for input signals. It also includes bypass capacitors for  $V_{CC}$  and bootstrap capacitors. The capacitors are located very close to the drive IC to avoid malfunction due to noise.

Dual current sensing options are provided: three dedicated on-board op-amps or embedded MCU op-amps; selection is performed through three jumpers.

The Hall/Encoder section (powered at 5 V or 3.3 V) completes the circuit.

2.1 schematic diagrams

Figure 3. STEVAL-IPMM15B board schematic (1 of 5)

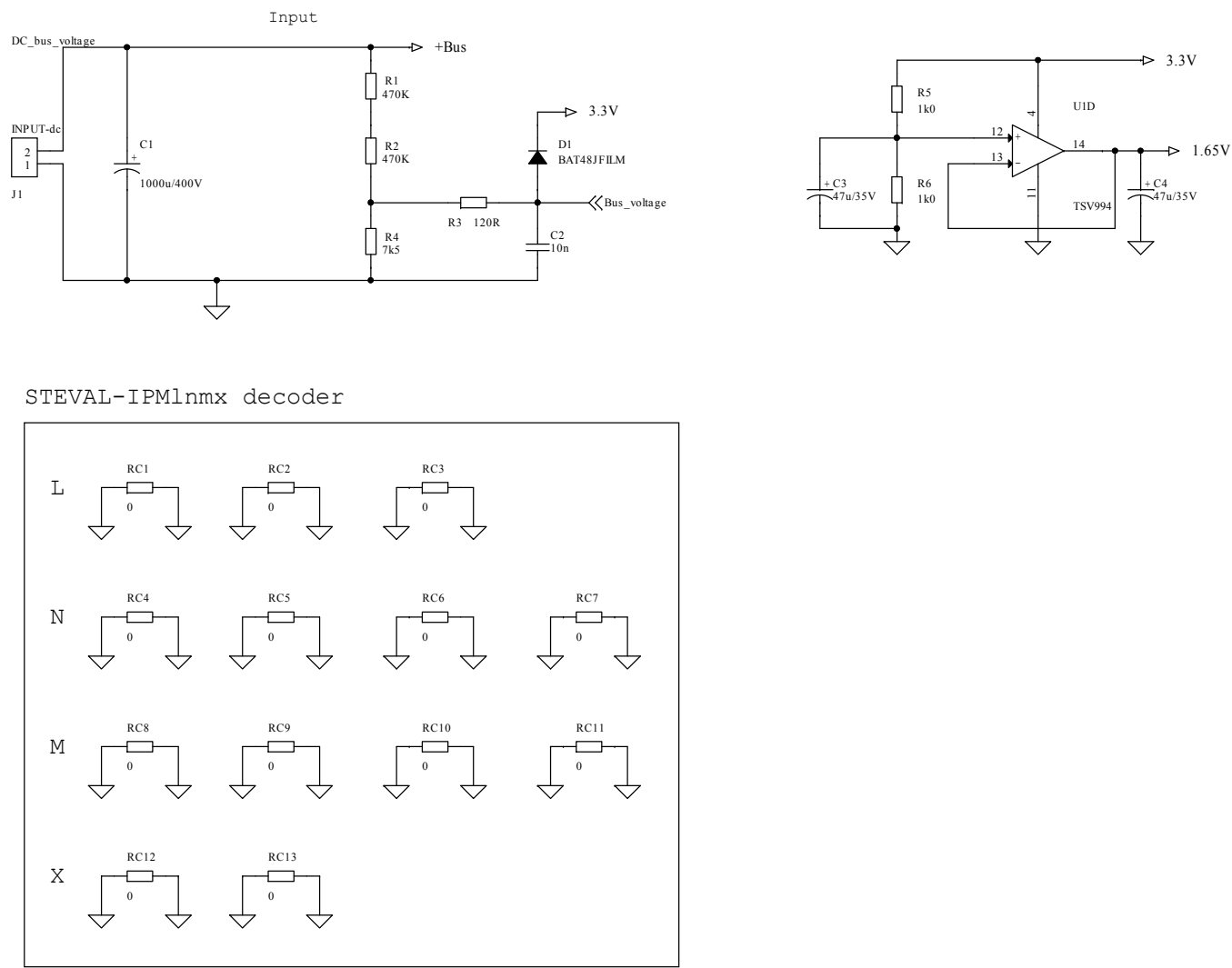


Figure 4. STEVAL-IPMM15B board schematic (2 of 5)

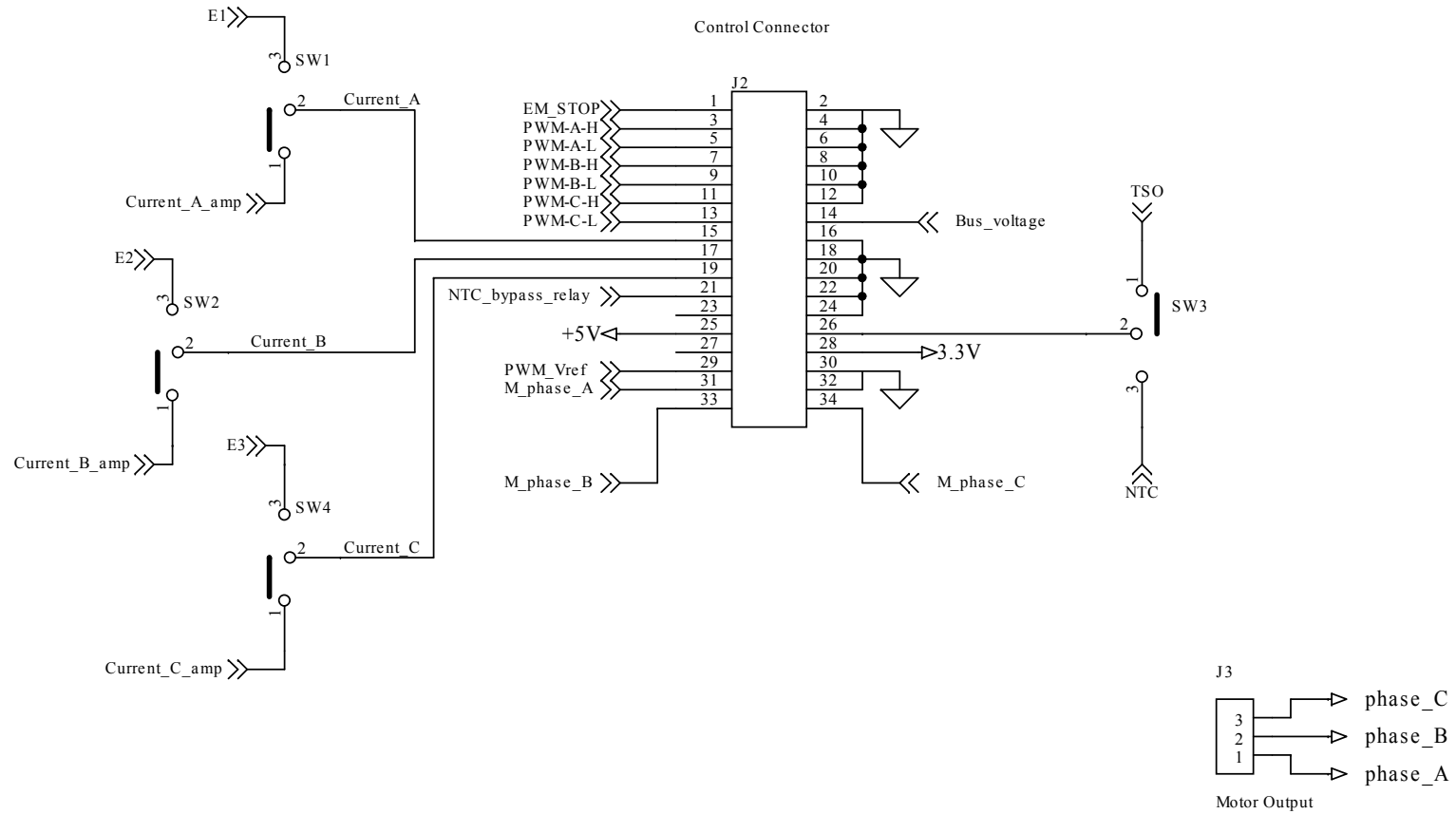


Figure 5. STEVAL-IPMM15B board schematic (3 of 5)

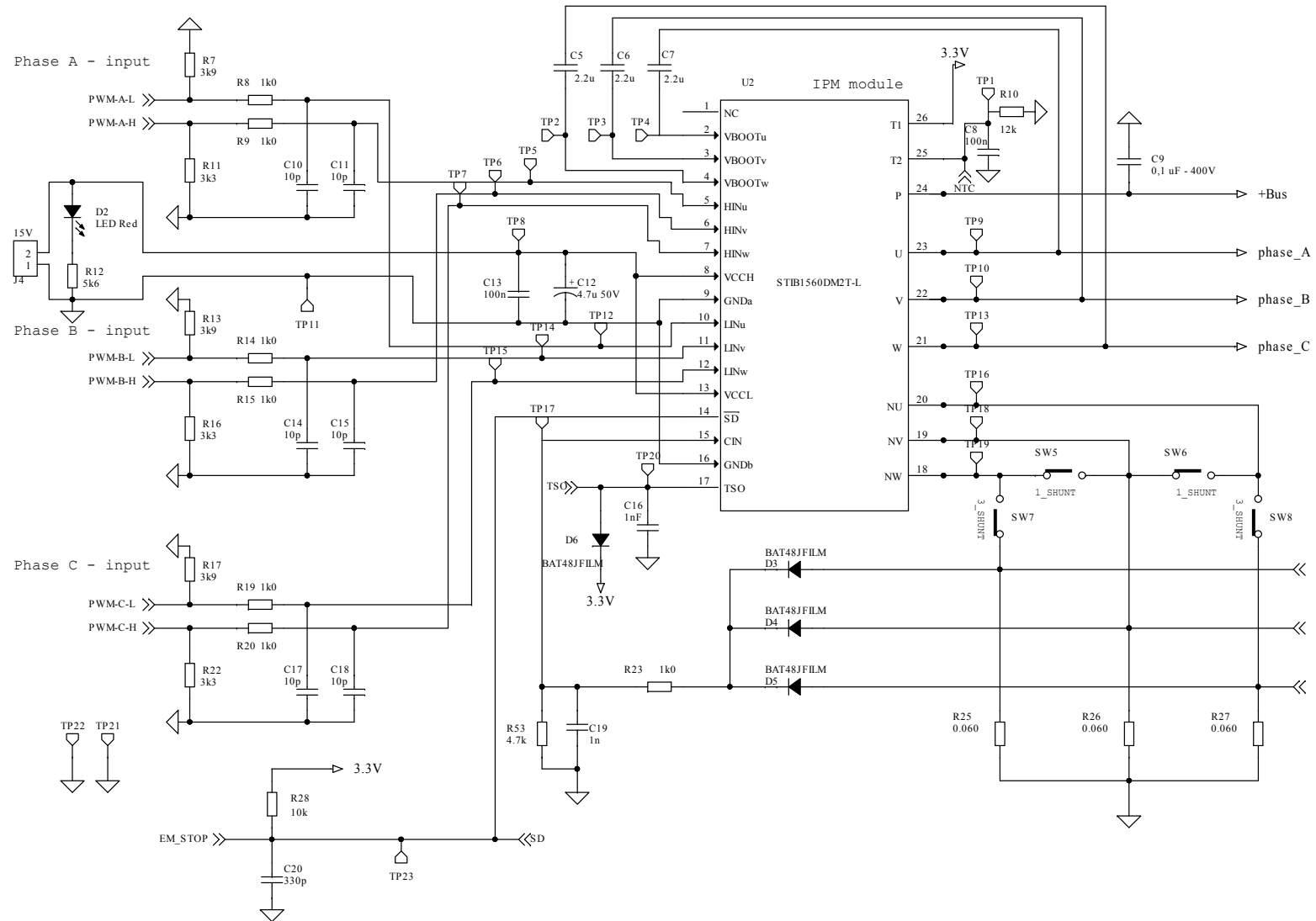


Figure 6. STEVAL-IPMM15B board schematic (4 of 5)

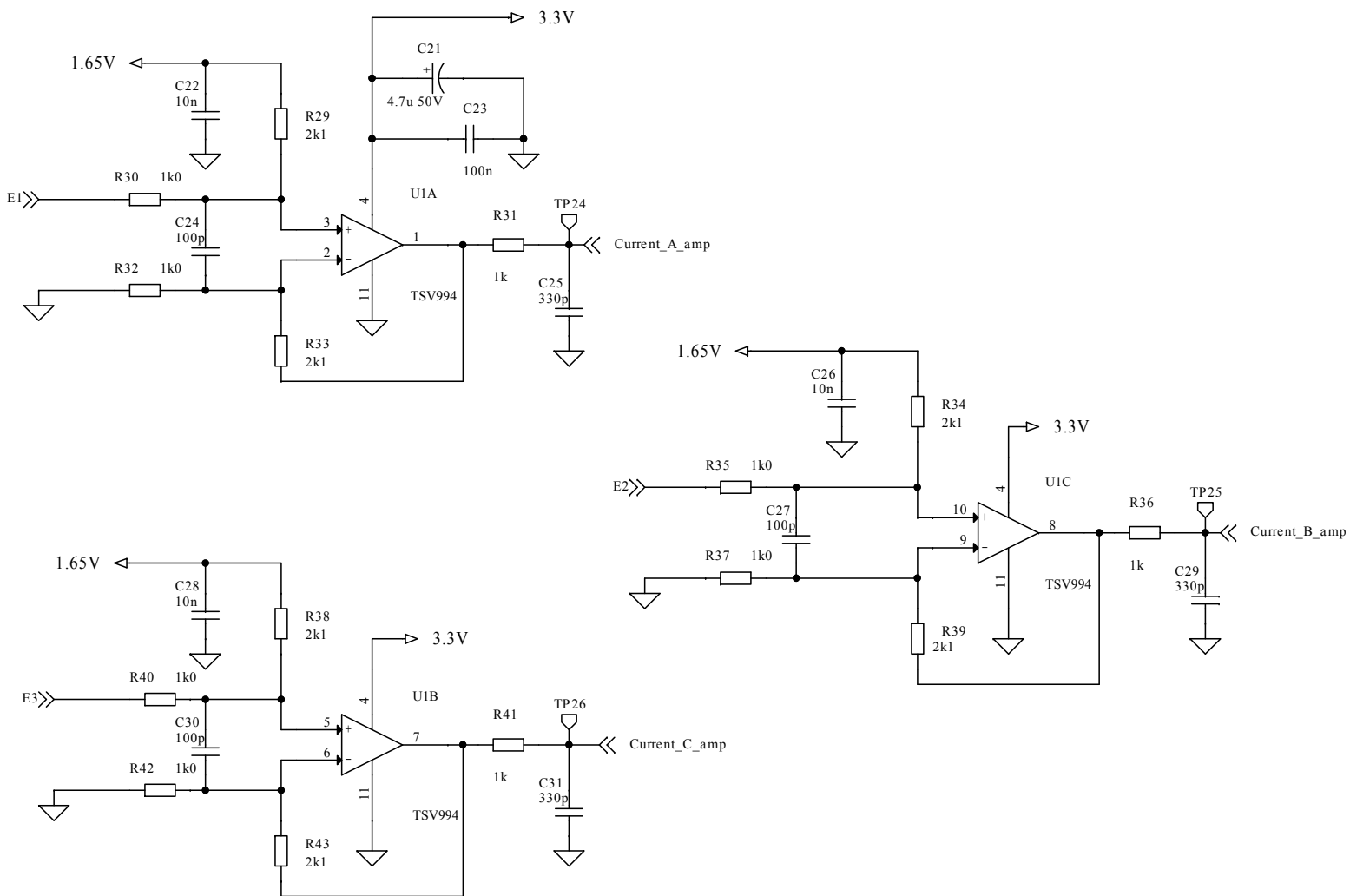
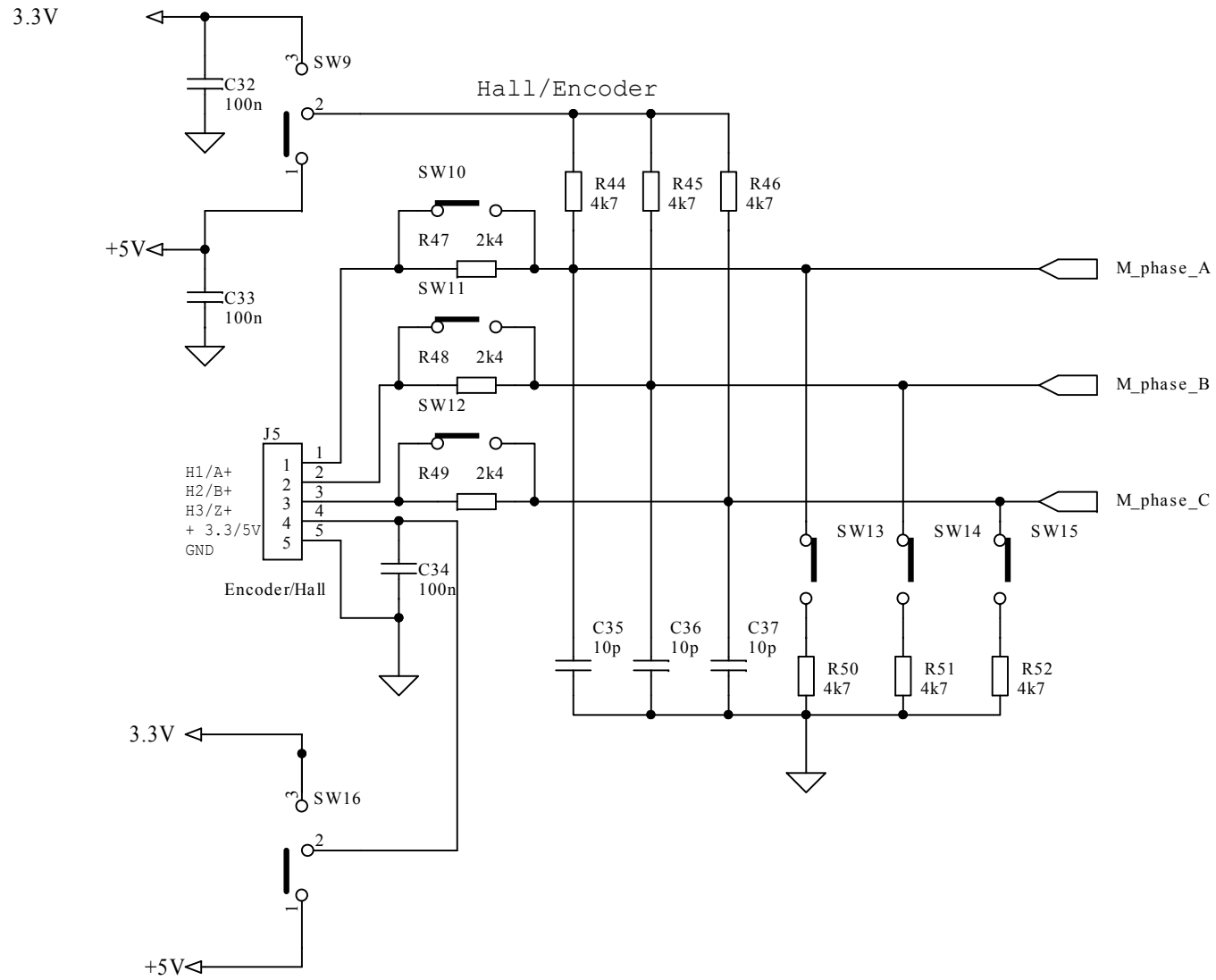


Figure 7. STEVAL-IPMM15B board schematic (5 of 5)



### 3 Main characteristics

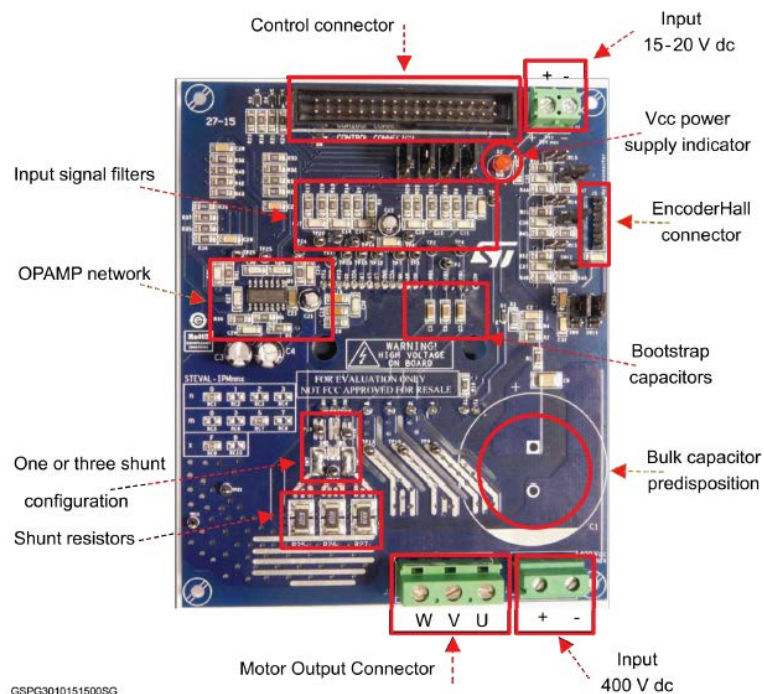
The board is designed to be compatible with DC supply from 125 VDC up to 400 VDC voltage.

A bulk capacitor according to the power level of the application must be mounted. The footprint is already provided on the board.

The SLLIMM integrates six MOSFET switches with high voltage gate drivers. Thanks to this integrated module, the system is specifically designed to achieve power inversion in a reliable and compact design. Such integration reduces the required PCB area and the simplicity of the design increases reliability.

In order to increase the flexibility, it can operate in single- or three-shunt configuration by modifying solder bridge jumper settings (see [Section 4.3.5 Single- or three-shunt selection](#)).

**Figure 8. STEVAL-IPMM15B architecture**



*Note:* This picture is indicative of the whole board family.

## 4 Filters and key parameters

### 4.1 Input signals

The input signals (LINx and HINx), able to drive the internal MOSFETs, are active high. A 100 k $\Omega$  (typ.) pull-down resistor is built-in for each input signal. In order to prevent input signal oscillation, an RC filter was added on each input and placed as close as possible to the IPM. The filter is designed using a time constant of 10 ns (1 k $\Omega$  and 10 pF).

### 4.2 Bootstrap capacitor

In the 3-phase inverter, the emitters of the low side MOSFETs are connected to the negative DC bus (VDC-) as common reference ground, which allows all low side gate drivers to share the same power supply, while the emitter of high side MOSFETs is alternately connected to the positive (VDC+) and negative (VDC-) DC bus during running conditions.

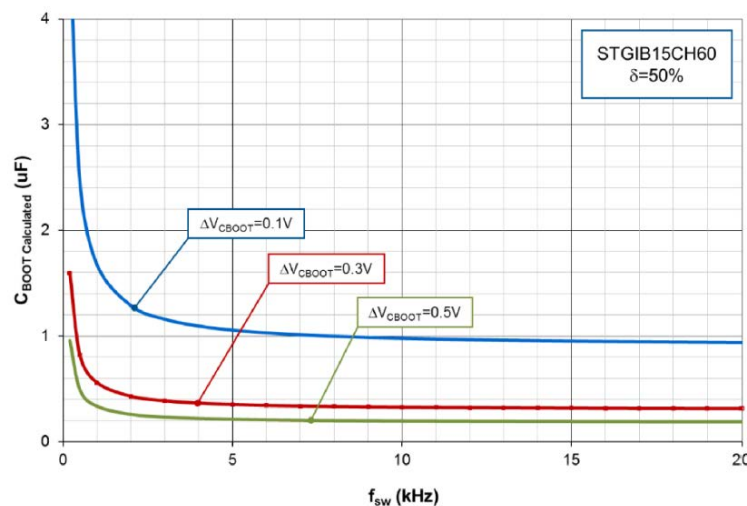
A bootstrap method is a simple and cheap solution to supply the high voltage section. This function is normally accomplished by a high voltage fast recovery diode. The SLLIMM 2nd series family includes a patented integrated structure that replaces the external diode. It is realized with a high voltage DMOS functioning as diode with series resistor. An internal charge pump provides the DMOS driving voltage. The value of the CBOOT capacitor should be calculated according to the application condition.

This curve is taken from application note AN4768 (available on [www.st.com](http://www.st.com)); calculations are based on the STGIB15CH60TS-L device, which represents the worst case scenario for this kind of calculation.

Figure 9. C<sub>BOOT</sub> graph selection shows the behavior of C<sub>BOOT</sub> (calculated) versus switching frequency (f<sub>sw</sub>), with different values of  $\Delta V_{CBOOT}$  for a continuous sinusoidal modulation and a duty cycle  $\delta = 50\%$ .

The boot capacitor must be two or three times larger than the C<sub>BOOT</sub> calculated in the graph. For this design, a value of 2.2  $\mu$ F was selected.

Figure 9. C<sub>BOOT</sub> graph selection



### 4.3 Overcurrent protection

The SLLIMM 2nd series integrates a comparator for fault sensing purposes. The comparator has an internal voltage reference VREF (510 mV typ.) connected to the inverting input, while the non-inverting input available on the CIN pin can be connected to an external shunt resistor to implement the overcurrent protection function.

When the comparator triggers, the device enters the shutdown state.

The comparator output is connected to the SD pin in order to send the fault message to the MCU.

### 4.3.1

#### SD Pin

The  $\overline{SD}$  is an input/output pin (open drain type if used as output). Taking into account the voltage reference on SD (3.3 V), a pull up resistor of 10 k $\Omega$  (R28) is used to guarantee the right bias and consequently to keep the current on the open drain DMOS ( $I_{od}$ ) lower than 3 mA.

The filter on  $\overline{SD}$  (R28 and C20) has to be sized to obtain the desired re-starting time after a fault event and placed as close as possible to the  $\overline{SD}$  pin.

A shutdown event can be managed by the MCU, in this case the  $\overline{SD}$  functions as the input pin.

Conversely, the  $\overline{SD}$  functions as an output pin when an overcurrent or undervoltage condition is detected.

### 4.3.2

#### Fault management

The SLLIMM 2nd series integrates a specific kind of fault management, useful when SD is functioning as output, able to identify the type of fault event.

As previously described, as soon as a fault occurs, the open-drain (DMOS) is activated and LVGx outputs are forced low.

Two types of fault can be signaled:

- Overcurrent (OC) sensed by the internal comparator (CIN);
- Undervoltage (UVLO) on supply voltage (VCC).

Each fault enables the SD open drain for a different time (see the table below).

The duration of a shutdown event therefore tells us the type of failure that has occurred.

**Table 1. Fault timing**

| Symbol | Parameter                  | Event time                                                        | SD open-drain enable time result |
|--------|----------------------------|-------------------------------------------------------------------|----------------------------------|
| OC     | Overcurrent event          | $\leq 24 \mu s$                                                   | 24 $\mu s$                       |
|        |                            | $> 24 \mu s$                                                      | OC time                          |
| UVLO   | Undervoltage lockout event | $\leq 70 \mu s$                                                   | 70 $\mu s$                       |
|        |                            | $> 70 \mu s$ until VCC_LS exceeds the VCC_LS UV turn on threshold | UVLO time                        |

*Note:* typical value ( $T_J = -40^\circ C$  to  $125^\circ C$ )

*Note:* without contribution of RC network on SD

Figure 10. SD failure due to overcurrent shows a shutdown as the result of an overcurrent event. During the overcurrent, the voltage on the comparator (CIN) exceeds the threshold (0.51 V typ.) and the shutdown is able to stop the application. In this case, the SD event time is about 24  $\mu$ s (for OC event less than 24  $\mu$ s).

Figure 10. SD failure due to overcurrent

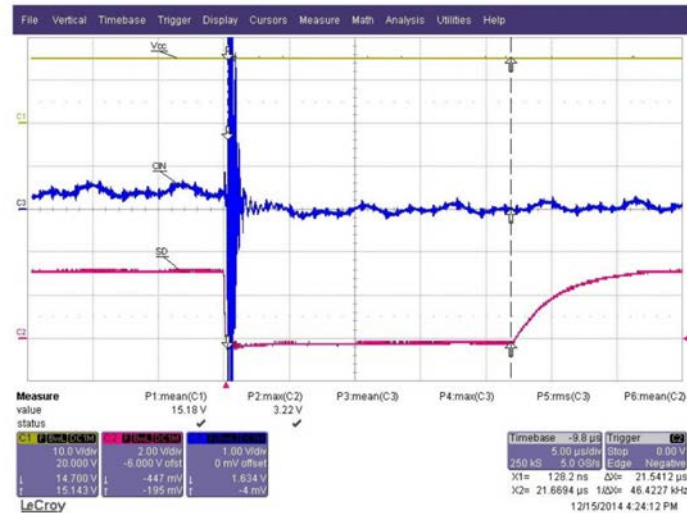


Figure 11. SD failure due to undervoltage (UVLO below 70  $\mu$ s) shows the shutdown event as the result of an undervoltage condition on the VCC supply. If VCC drops below the undervoltage threshold, the shutdown can stop the application. If the voltage on VCC rises above the VCC on threshold in less than 70  $\mu$ s, the SD event time is about 70  $\mu$ s.

Figure 11. SD failure due to undervoltage (UVLO below 70  $\mu$ s)

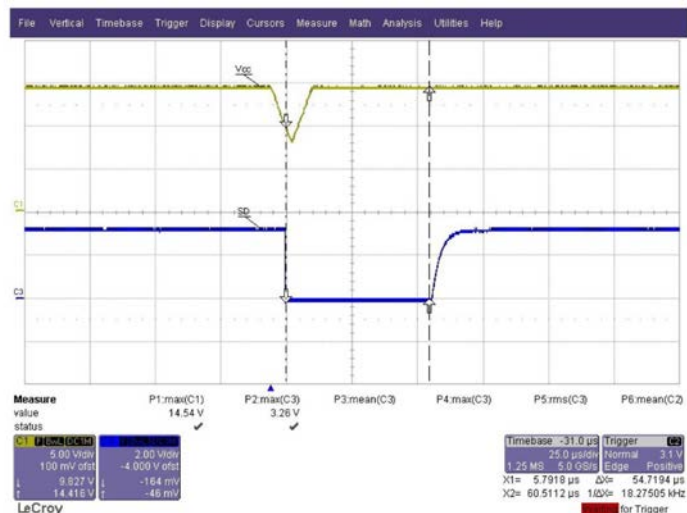
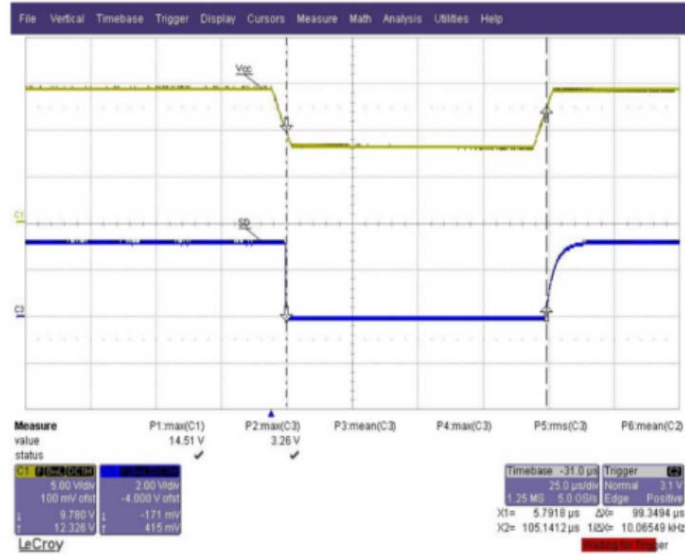


Figure 12. SD failure due to undervoltage (UVLO above 70  $\mu$ s) shows the shutdown event as the result of an undervoltage condition on the  $V_{CC}$  supply. In this case, the drop on  $V_{CC}$  is greater than 70  $\mu$ s. The SD event time is the same as the duration of drop.

Figure 12. SD failure due to undervoltage (UVLO above 70  $\mu$ s)



### 4.3.3

#### Shunt resistor selection

The value of the shunt resistor is calculated by the following equation:

$$R_{SH} = \frac{V_{ref}}{I_{OC}} \quad (1)$$

Where  $V_{ref}$  is the internal comparator (CIN) (0.51 V typ.) and  $I_{OC}$  is the current of overcurrent detection level. The maximum value of overcurrent protection level should be set less than the pulsed collector current in the datasheet. In this design the over current threshold level is fixed @  $I_{OC} = 13$  A.

$$R_{SH} = \frac{V_{ref} \cdot \left( \frac{R23 + R53}{R53} \right) + V_F}{I_{OC}} = \frac{0.51 \cdot \left( \frac{1000 + 4700}{4700} \right) + 0.18}{13} = 0.0614 \Omega \quad (2)$$

Where  $V_F$  is the voltage drop across diodes D3, D4 and D5.

The commercial value chosen was 0.06  $\Omega$  to which corresponds a level of 13.1 A.

The power rating of the shunt resistor is calculated by the following equation:

$$P_{SH} = \frac{1}{2} \cdot \frac{I_{load(max)}^2 \cdot R_{SH} \cdot margin}{Deratingratio} \quad (3)$$

Where:

- $I_{load(max)}$ : Maximum load current of inverter
- $R_{SH}$ : Shunt resistor value at  $T_c = 25^\circ\text{C}$
- Derating ratio: Power derating ratio of shunt resistor @  $100^\circ\text{C}$
- Margin: Safety margin of 30%

$I_{load(max)}$  is calculated considering the RMS value of the IPM nominal current including a safety margin.

$$I_{load(max)} = \frac{I_{nom(@80^\circ\text{C})}}{\sqrt{2}} \cdot 0.85 = 6.0 A_{rms} \quad (4)$$

Power shunt value is:

(5)

$$P_{SH} = \frac{1}{2} \cdot \frac{6.0^2 \cdot 0.06 \cdot 1.3}{0.8} = 1.772W$$

Considering the commercial value, 2W shunt resistor was selected.

Based on the previous equations and conditions, minimum shunt resistance and power rating is summarized in Section 4.3.3 table.

**Table 2. Shunt selection**

| Device         | OCP <sub>(peak)</sub><br>[A] | I <sub>load(max)</sub><br>[Arms] | R <sub>SHUNT</sub><br>[Ω] | Shunt power rating<br>P <sub>SH</sub> [W] |
|----------------|------------------------------|----------------------------------|---------------------------|-------------------------------------------|
| STIB1560DM2T-L | 13.1                         | 6.0                              | 0.06                      | 2                                         |

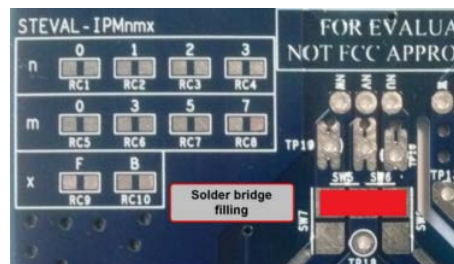
#### 4.3.4 RC filter

An RC filter network is required to prevent undesired short circuit operation due to the noise on the shunt resistor. In this design, the RC filter, composed of R23, R18, R21, R24 and C19, has a constant time of about 1.3 μs. Adding the turn-off propagation delay of the gate driver and the MOSFET turn-off time (hundreds of nanoseconds in total), the total delay time is less than 5 μs of short circuit withstand MOSFET time.

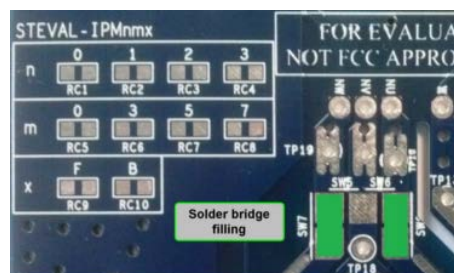
#### 4.3.5 Single- or three-shunt selection

Single- or three-shunt resistor circuits can be adopted by setting the solder bridges SW5, SW6, SW7 and SW8. The figures below illustrate how to set up the two configurations.

**Figure 13. One-shunt configuration**



**Figure 14. Three-shunt configuration**



## 5 Current sensing amplifying network

The STEVAL-IPMM15B motor control evaluation board can be configured to run in three-shunt or single-shunt configurations for field oriented control (FOC).

The current can be sensed thanks to the shunt resistor and amplified by using the on board operational amplifiers or by the MCU (if equipped with op-amp).

Once the shunt configuration is chosen by setting solder bridge on SW5, SW6, SW7 and SW8 (as described in Section 4.3.5 Single- or three-shunt selection), the user can choose to send the voltage shunt to the MCU amplified or unamplified.

Single-shunt configuration requires a single op amp and three-shunt configuration requires three op amps; therefore, in single-shunt configuration, the only voltage which is sent to the MCU to control the sensing is connected to phase V through SW2.

SW1, SW2, SW4 can select which signals are sent to micro, as described below:

**Table 3. Op-amp sensing configuration**

| Symbol | Configuration | Bridge | Sensing         |
|--------|---------------|--------|-----------------|
| SW1    | Single        | 1-2    | open            |
|        | Shunt         | 2-3    | open            |
|        | Three         | 1-2    | On-board op-amp |
|        | Shunt         | 2-3    | MCU op-amp      |
| SW2    | Single        | 1-2    | On-board op-amp |
|        | Shunt         | 2-3    | MCU op-amp      |
|        | Three         | 1-2    | On-board op-amp |
|        | Shunt         | 2-3    | MCU op-amp      |
| SW4    | Single        | 1-2    | open            |
|        | Shunt         | 2-3    | open            |
|        | Three         | 1-2    | On-board op-amp |
|        | Shunt         | 2-3    | MCU op-amp      |

The operational amplifier TSV994 used on amplifying networks has a 20 MHz gain bandwidth and operates with a single positive supply of 3.3 V.

The amplification network must allow bidirectional current sensing, so that an output offset  $V_O = +1.65$  V represents zero current.

Referencing the STIB1560DM2T-L (IOCP = 13.1 A; RSHUNT = 0.06Ω), the maximum measurable phase current, considering that the output swings from +1.65 V to +3.3 V (MCU supply voltage) for positive currents and from +1.65 V to 0 for negative currents is:

$$MaxMeasCurrent = \frac{\Delta V}{r_m} = 13.1A \quad (6)$$

$$r_m = \frac{\Delta V}{MaxMeasCurrent} = \frac{1.65}{13.1} = 0.126\Omega \quad (7)$$

The overall trans-resistance of the two-port network is:

$$r_m = R_{SHUNT} \cdot AMP = 0.06 \cdot AMP = 0.126\Omega \quad (8)$$

(9)

$$AMP = \frac{r_m}{R_{SHUNT}} = \frac{0.126}{0.06} = 2.1$$

Finally choosing  $R_a=R_b$  and  $R_c=R_d$ , the differential gain of the circuit is:

(10)

$$AMP = \frac{R_c}{R_a} = 2.1$$

An amplification gain of 2.1 was chosen. The same amplification is obtained for all the other devices, taking into account the OCP current and the shunt resistance, as described in Table 1.

The RC filter for output amplification is designed to have a time constant that matches noise parameters in the range of 1.5  $\mu$ s:

(11)

$$4 \cdot t = 4 \cdot R_e \cdot C_c = 1.5\mu s$$

(12)

$$C_c = \frac{1.5\mu s}{4 \cdot 1000} = 375pF(330pF_{selected})$$

**Table 4. Amplifying networks**

| Phase   | Amplifying network |       |       | RC filter |       |       |
|---------|--------------------|-------|-------|-----------|-------|-------|
|         | $R_a$              | $R_b$ | $R_c$ | $R_d$     | $R_e$ | $C_c$ |
| Phase U | R30                | R32   | R29   | R33       | R31   | C25   |
| Phase V | R35                | R37   | R34   | R39       | R36   | C29   |
| Phase W | R40                | R42   | R38   | R43       | R41   | C31   |

## 6 Temperature monitoring

The SLLIMM 2nd series family integrates a temperature sensor (VTSO) on the low side gate driver and an NTC thermistor placed close to the power stage.

They can be selected via SW3.

The board is designed to use both of them to monitor the internal IPM temperature through the MCU.

### 6.1 Thermal sensor (VTSO)

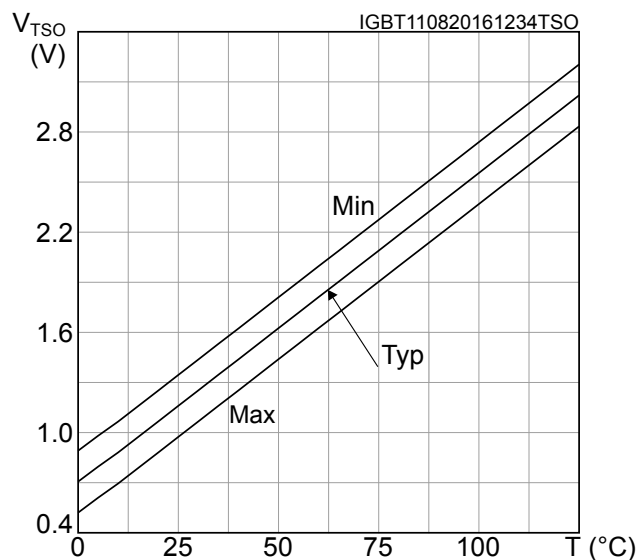
A voltage proportional to the temperature is available on the TSO pin (17) and easily measurable on the TP20 test pin.

To improve noise immunity, a 1 nF (C16) capacitor filter is placed on this pin.

The thermal sensor does not need any pull down resistors.

The following graph shows typical voltage variation as a function of temperature.

Figure 15. Thermal sensor voltage vs temperature



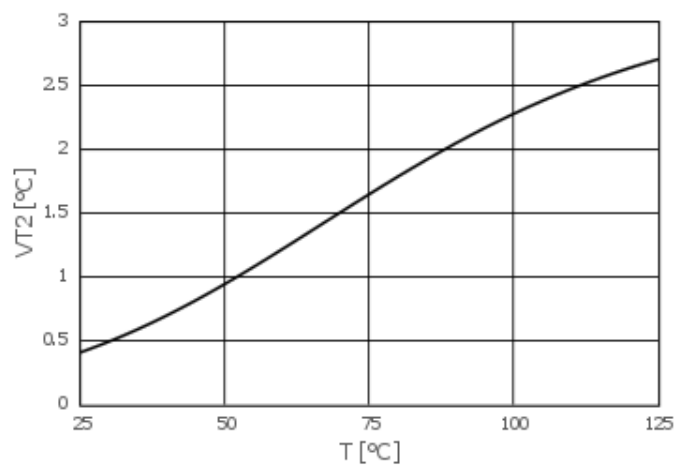
### 6.2 NTC Thermistor

The embedded thermistor (85 k $\Omega$  at 25  $^{\circ}\text{C}$ ) in the IPM is connected between pins T1 and T2 (26, 25).

A 12 k $\Omega$  pull down resistor (R10) ensures that the voltage variation on the NTC as a function of temperature is almost linear. This voltage is easily monitored on TP1 test pin.

The figure below shows the typical voltage on T2 as function of temperature.

Figure 16. NTC voltage vs temperature



## 7 Firmware configuration for STM32 PMSM FOC SDK

The following table summarizes the parameters which customize the latest version of the ST FW motor control library for permanent magnet synchronous motor (PMSM): STM32 PMSM FOC SDK for this [STEVAL-IPMM15B](#).

**Table 5. ST motor control workbench GUI parameters**

| Block                   | Parameter                  | Value                                                                                           |
|-------------------------|----------------------------|-------------------------------------------------------------------------------------------------|
| Over current protection | Comparator threshold       | $V_{ref} \cdot \left( \frac{R23 + R53}{R53} \right) + V_F = 0.8V$ <sup>(13)</sup>               |
|                         | Overcurrent network offset | 0                                                                                               |
|                         | Overcurrent network gain   | Comparator threshold (see <a href="#">equation</a> ) / $I_{ocp}$ (see Shunt resistor selection) |
| Bus voltage sensing     | Bus voltage divider        | 1/125                                                                                           |
| Rated bus voltage info  | Min rated voltage          | 125 V                                                                                           |
|                         | Max rated voltage          | 400 V                                                                                           |
|                         | Nominal voltage            | 325 V                                                                                           |
| Current sensing         | Current reading typology   | Single- or three-shunt                                                                          |
|                         | Shunt resistor value       | See shunt value in Shunt resistor selection                                                     |
|                         | Amplifying network gain    | 2.1                                                                                             |
| Command stage           | Phase U Driver             | HS and LS: Active high                                                                          |
|                         | Phase V Driver             | HS and LS: Active high                                                                          |
|                         | Phase W Driver             | HS and LS: Active high                                                                          |

## 8 Connectors, jumpers and test pins

Table 6. Connectors

| Connector | Description/pinout                                                                                                                                                                                                                                  |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| J2        | 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 - heat sink temperature                                                                                                                                                                                                                          |
|           | 27 - PFC sync.                                                                                                                                                                                                                                      |
|           | 28 - VDD_m                                                                                                                                                                                                                                          |
|           | 29 - PWM VREF                                                                                                                                                                                                                                       |
|           | 30 - GND                                                                                                                                                                                                                                            |
|           | 31 - measure phase A                                                                                                                                                                                                                                |
|           | 32 - GND                                                                                                                                                                                                                                            |
|           | 33 - measure phase B                                                                                                                                                                                                                                |
|           | 34 - measure phase C                                                                                                                                                                                                                                |
| J3        | Motor connector <ul style="list-style-type: none"> <li>phase A</li> <li>phase B</li> <li>phase C</li> </ul>                                                                                                                                         |
| J4        | VCC supply (20 VDC max) <ul style="list-style-type: none"> <li>positive</li> <li>negative</li> </ul>                                                                                                                                                |
| J5        | Hall sensors / encoder input connector <ol style="list-style-type: none"> <li>Hall sensors input 1 / encoder A+</li> <li>Hall sensors input 2 / encoder B+</li> <li>Hall sensors input 3 / encoder Z+</li> <li>3.3 or 5 Vdc</li> <li>GND</li> </ol> |
| J7        | Supply connector (DC – 125V to 400 V) <ol style="list-style-type: none"> <li>+ (positive terminal)</li> <li>- (negative terminal)</li> </ol>                                                                                                        |

Table 7. Jumpers

| Jumper           | Description                                                               |             |
|------------------|---------------------------------------------------------------------------|-------------|
| SW3              | TSO/NTC                                                                   |             |
|                  | TSO: jumper on 1-2                                                        |             |
|                  | NTC: jumper on 2-3                                                        |             |
| SW1              | To choose current U to send to control board:                             |             |
|                  | Jumper on 1-2: from amplification                                         |             |
|                  | Jumper on 2-3: directly from motor output                                 |             |
| SW2              | To choose current V to send to control board                              |             |
|                  | Jumper on 1-2: from amplification                                         |             |
|                  | Jumper on 2-3: directly from motor output                                 |             |
| SW4              | To choose current W to send to control board:                             |             |
|                  | Jumper on 1-2: from amplification                                         |             |
|                  | Jumper on 2-3: directly from motor output                                 |             |
| SW13             | To modify phase A hall sensor network                                     |             |
| SW14             | To modify phase B hall sensor network                                     |             |
| SW15             | To modify phase C hall sensor network                                     |             |
| SW9, SW16        | To choose input power for Hall/Encoder                                    |             |
|                  | Jumper on 1-2: 5 V                                                        |             |
|                  | Jumper on 2-3: 3.3 V                                                      |             |
| SW5, SW6SW7, SW8 | To choose one-shunt or three-shunt configuration. (Through solder bridge) |             |
|                  | SW5, SW6 closed<br>SW7, SW8 open                                          | one shunt   |
|                  | SW5, SW6 open<br>SW7, SW8 closed                                          | three shunt |
|                  |                                                                           |             |

**Table 8. Test pins**

| Test pin | Description                             |
|----------|-----------------------------------------|
| TP1      | NTC (T2 pin)                            |
| TP2      | VBOOTw                                  |
| TP3      | VBOOTv                                  |
| TP4      | VBOOTu                                  |
| TP5      | HinU (high side U control signal input) |
| TP6      | HinV (high side V control signal input) |
| TP7      | HinW (high side W control signal input) |
| TP8      | VCCH                                    |
| TP9      | phase A (U pin)                         |
| TP10     | phase B (V pin)                         |
| TP11     | Ground                                  |
| TP12     | LinU (high side U control signal input) |
| TP13     | phase C (W pin)                         |
| TP14     | LinV (high side V control signal input) |
| TP15     | LinW (high side W control signal input) |
| TP16     | Negative DC input for U phase           |
| TP17     | CIN                                     |
| TP18     | Negative DC input for V phase           |
| TP19     | Negative DC input for W phase           |
| TP20     | TSO (TSO pin)                           |
| TP21     | Ground                                  |
| TP22     | Ground                                  |
| TP23     | SD (shutdown pin)                       |
| TP24     | Current_A_amp                           |
| TP25     | Current_B_amp                           |
| TP26     | Current_C_amp                           |

## 9 PCB design guide

Optimization of PCB layout for high voltage, high current and high switching frequency applications is a critical point. PCB layout is a complex matter as it includes several aspects, such as length and width of track and circuit areas, but also the proper routing of the traces and the optimized reciprocal arrangement of the various system elements in the PCB area.

A good layout can help the application to properly function and achieve expected performance. On the otherhand, a PCB without a careful layout can generate EMI issues, provide overvoltage spikes due to parasitic inductance along the PCB traces and produce higher power loss and even malfunction in the control and sensing stages.

In general, these conditions were applied during the design of the board:

- PCB traces designed as short as possible and the area of the circuit (power or signal) minimized to avoid the sensitivity of such structures to surrounding noise
- Good distance between switching lines with high voltage transitions and the signal line sensitive to electrical noise
- The shunt resistors were placed as close as possible to the low side pins of the SLLIMM. To decrease the parasitic inductance, a low inductance type resistor (SMD) was used
- RC filters were placed as close as possible to the SLLIMM pins in order to increase their efficiency

### 9.1 Layout of reference board

All the components are inserted on the top of the board. Only the IPM module is inserted on the bottom to allow the insertion of a suitable heatsink for the application.

**Figure 17. Silk screen and etch - top side**

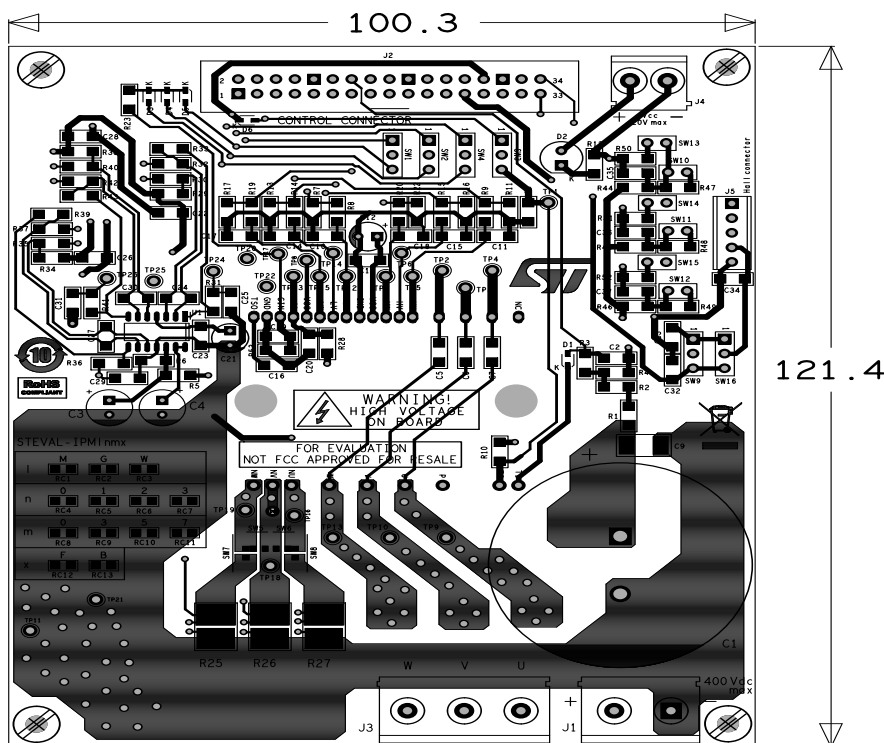
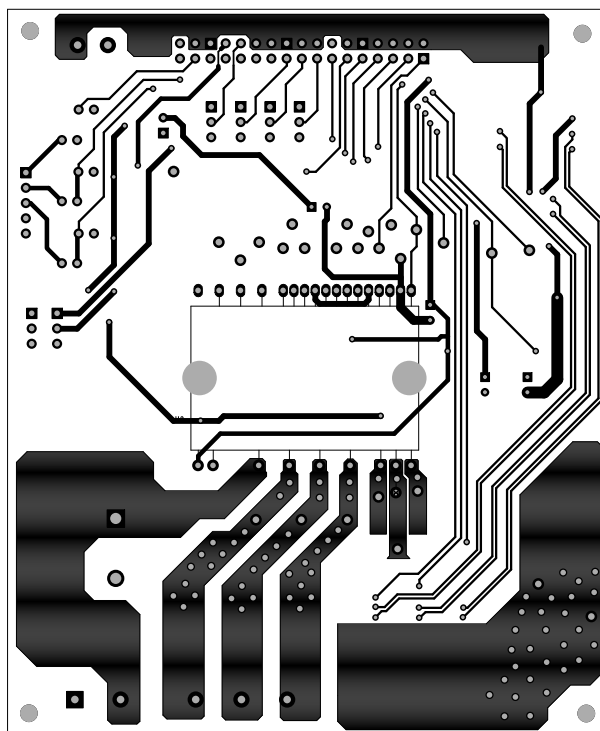


Figure 18. Silk screen and etch - bottom side



## 10 Bill of materials

**Table 9. STEVAL-IPMM15B bill of materials**

| Item | Q.ty | Ref.                                | Part / Value             | Description                     | Manufacturer                   | Order code         |
|------|------|-------------------------------------|--------------------------|---------------------------------|--------------------------------|--------------------|
| 1    | 4    | C2,C22,C26,C28                      | 10 nF                    | Capacitor, SMD 1206             | AVX                            | 12065C103KAT2A     |
| 2    | 9    | C10,C11,C14,C15,C17,C18,C35,C36,C37 | 10 pF                    | Capacitor, SMD 1206             | AVX                            | 12061A100JAT2A     |
| 3    | 4    | C20,C25,C29,C31                     | 330 pF                   | Capacitor, SMD 1206             | AVX                            | 12065A331JAT2A     |
| 4    | 3    | C5,C6,C7                            | 2.2 uF                   | Capacitor, SMD 1206             | Murata                         | GCM31MR71E225KA57L |
| 5    | 6    | C8,C13,C23,C32,C33,C34              | 100 nF                   | Capacitor, SMD 1206             | AVX                            | 12065C104KAZ2A     |
| 6    | 2    | C12,C21                             | 4.7 uF                   | Electrolytic Capacitor          | any                            |                    |
| 7    | 2    | C19,C16                             | 1 nF                     | Capacitor, SMD 1206             | Kemet                          | C1206C102K5RACTU   |
| 8    | 1    | C9                                  | 0.1 uF                   | Capacitor, SMD 1812             | Murata                         | GRM43DR72J104KW01L |
| 9    | 3    | C24,C27,C30                         | 100 pF                   | Capacitor, SMD 1206             | Kemet                          | C1206C101J1GACTU   |
| 10   | 2    | C3,C4                               | 47 uF                    | Electrolytic Capacitor          | any                            |                    |
| 11   | 5    | D1,D3,D4,D5,D6                      | Diode BAT48J             | Schottky Diode, SOD323          | STMicroelectronics             | BAT48J             |
| 12   | 1    | D2                                  | LED Red                  | LED 3 mm, 2 mA, universal       | Ledtech                        | L4RR3000G1EP4      |
| 13   | 1    | J2                                  | Connector 34P            | 445-6043-2-ND connector 34-pins | RS                             | 625-7347           |
| 14   | 1    | J3                                  | Connector - 7,5 mm - 3P  | Connector - 7 mm - 3 pole       | TE Connectivity AMP Connectors | 282845-3           |
| 15   | 1    | J4                                  | Conector - 5 mm - 2P     | Connector - 5 mm - 2 pole       | Phoenix Contact                | 1935161            |
| 16   | 1    | J1                                  | Conector - 7.5 mm - 2P   | Connector - 7 mm - 2 pole       | On Shore Technology Inc        | OSTVI024152        |
| 17   | 1    | J5                                  | Connector - 2.54 mm - 5P | Five pins of pin header         | RS                             | W81136T3825RC      |
| 18   | 2    | R1,R2                               | 470 kΩ                   | Resistor, SMD 1206              | any                            |                    |
| 19   | 1    | R4                                  | 7.5 kΩ                   | Resistor, SMD 1206              | Panasonic                      | ERJP08F7501V       |
| 20   | 1    | R3                                  | 120 Ω                    | Resistor, SMD 1206              | any                            |                    |
| 21   | 3    | R7,R13,R17                          | 3.9 kΩ                   | Resistor, SMD 1206              | any                            |                    |

| Item | Q.ty | Ref.                                                                                                                     | Part / Value                             | Description              | Manufacturer       | Order code      |
|------|------|--------------------------------------------------------------------------------------------------------------------------|------------------------------------------|--------------------------|--------------------|-----------------|
| 22   | 18   | R5,R6,R8,R9,R14,R15,R19,R20,R23,R30,R32,R31,R36,R35,R41,R42,R40,R37                                                      | 1 kΩ                                     | Resistor, SMD 1206       | any                |                 |
| 23   | 3    | R11,R16,R22                                                                                                              | 3.3 kΩ                                   | Resistor, SMD 1206       | any                |                 |
| 24   | 1    | R28                                                                                                                      | 10 kΩ                                    | Resistor, SMD 1206       | any                |                 |
| 25   | 1    | R10                                                                                                                      | 12 kΩ                                    | Resistor, SMD 1206       | any                |                 |
| 26   | 6    | R29,R33,R34,R38,R39,R43                                                                                                  | 2.1 kΩ                                   | Resistor, SMD 1206       | any                |                 |
| 27   | 1    | R12                                                                                                                      | 5.6 kΩ                                   | Resistor, SMD 1206       | any                |                 |
| 28   | 3    | R25,R26,R27                                                                                                              | 0,060 Ω                                  | Resistor, SMD 2816       | Vishay / Dale      | WSL2816R0600FEB |
| 29   | 7    | R44,R45,R46,R50,R51,R52,R53                                                                                              | 4.7 kΩ                                   | Resistor, SMD 1206       | any                |                 |
| 30   | 3    | R47,R48,R49                                                                                                              | 2.4 kΩ                                   | Resistor, SMD 1206       | any                |                 |
| 31   | 6    | SW1,SW2,SW3,SW4,SW9,SW16                                                                                                 | Jumper 2.54                              | Three pins of pin header | RS                 | W81136T3825RC   |
| 32   | 6    | SW10,SW11,SW12,SW13,SW14,SW15                                                                                            | Jumper 2.54                              | Two pins of pin header   | RS                 | W81136T3825RC   |
| 33   | 12   | -                                                                                                                        | 2.54mm,low profile,connector             | -                        | RS                 | 881545-2        |
| 34   | 42   | SW7,SW8                                                                                                                  | Solder Bridge                            | -                        | -                  |                 |
| 35   | 2    | SW5,SW6                                                                                                                  | open                                     | -                        | -                  |                 |
| 36   | 26   | TP1,TP2,TP3,TP4,TP5,TP6,TP7,TP8,TP9,TP10,TP11,TP12,TP13,TP14,TP15,TP16,TP17,TP18,TP19,TP20,TP21,TP22,TP23,TP24,TP25,TP26 | PCB terminal 1mm                         | Test pin                 | KEYSTONE           | 5001            |
| 37   | 1    | U1                                                                                                                       | TSV994                                   | Op amp, SO14             | STMicroelectronics | TSV994          |
| 38   | 1    | U2                                                                                                                       | 3-phase inverter, 15A, 600V Power MOSFET | SDIP2B-26L type L1       | STMicroelectronics | STIB1560DM2T-L  |

| Item | Q.ty | Ref.                                                                                         | Part / Value      | Description        | Manufacturer    | Order code   |
|------|------|----------------------------------------------------------------------------------------------|-------------------|--------------------|-----------------|--------------|
| 39   | 4    | RC1,RC5,RC10,RC13                                                                            | 0 OHM             | Resistor, SMD 0805 | ANY             |              |
| 40   | 9    | RC2,RC3,RC4,RC6,RC7,RC8,RC9,RC11,RC12                                                        | NOT ASSEMBLY      | NOT ASSEMBLY       | NOT ASSEMBLY    | NOT ASSEMBLY |
| 41   | 9    | to close<br>switch for:<br>SW1, SW2,<br>SW3, SW4,<br>SW9,<br>SW10,<br>SW11,<br>SW12,<br>SW16 | -                 | -                  | TE Connectivity | 1-881545-1   |
| 42   | 1    | PCB                                                                                          | 100.3x121.4x1.6mm |                    |                 |              |

## 11 Recommendations and suggestions

---

- The BOM list is not provided with a bulk capacitor already inserted in the PCB. However, the necessary space has been included (C1). In order to obtain a stable supply voltage, according to the application conditions and current ripple requirements, it's advisable to use an adequate bulk capacitor. For general motor control applications, an electrolytic capacitor of at least 100  $\mu\text{F}$  is suggested
- Similarly, the PCB does not come with a heat sink, it can be placed above the IPM on the back of the PCB with thermal conductive foil and screws. Heat sink  $R_{\text{TH}}$  value is an important factor for good thermal performance and depends on certain factors such as current phase, switching frequency, power factor and ambient temperature. For an adequate heat sink dimensioning, it is suggested to use ST PowerStudio software (STSW-POWERSTUDIO), available on [www.st.com](http://www.st.com).
- The board requires +5 V and +3.3 V to be supplied externally through the 34-pin motor control connector J2. Please refer to the relevant board manuals for information on key connections and supplies.

## 12 General safety instructions

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**Danger:**

*The evaluation board works with high voltage which could be deadly for the users. Furthermore all circuits on the board are not isolated from the line input. Due to the high power density, the components on the board as well as the heat sink can be heated to a very high temperature, which can cause a burning risk when touched directly. This board is intended for use by experienced power electronics professionals who understand the precautions that must be taken to ensure that no danger or risk may occur while operating this board.*

---

**Caution:** After the operation of the evaluation board, the bulk capacitor C1 (if used) may still store a high energy for several minutes. So it must be first discharged before any direct touching of the board.

**Important:**

*To protect the bulk capacitor C1, we strongly recommended using an external brake chopper after C1 (to discharge the high brake current back from the induction motor).*

## Revision history

**Table 10. Document revision history**

| Date        | Version | Changes          |
|-------------|---------|------------------|
| 14-Apr-2020 | 1       | Initial release. |

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