UM2246

User manual

# 800 W motor control power board based on STGIB8CH60TS-L SLLIMM™ 2nd series IPM

## Introduction

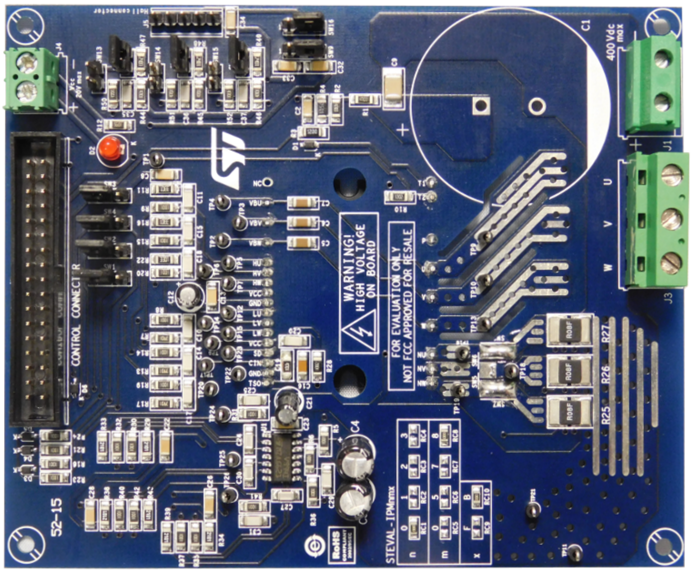
The STEVAL-IPM08B is a compact motor drive power board based on SLLIMM™ (small low-loss intelligent molded module) 2nd series (STGIB8CH60TS-L). It provides an affordable and easy-to-use solution for driving high power motors for a wide range of applications such as power white goods, air conditioning, compressors, power fans, high-end power tools and 3-phase inverters for motor drives in general. The IPM itself consists of short-circuit rugged IGBTs 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 $V_{CC}$ 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-IPM08B is compatible with ST's STM32-based control board, enabling designers to build a complete platform for motor control.

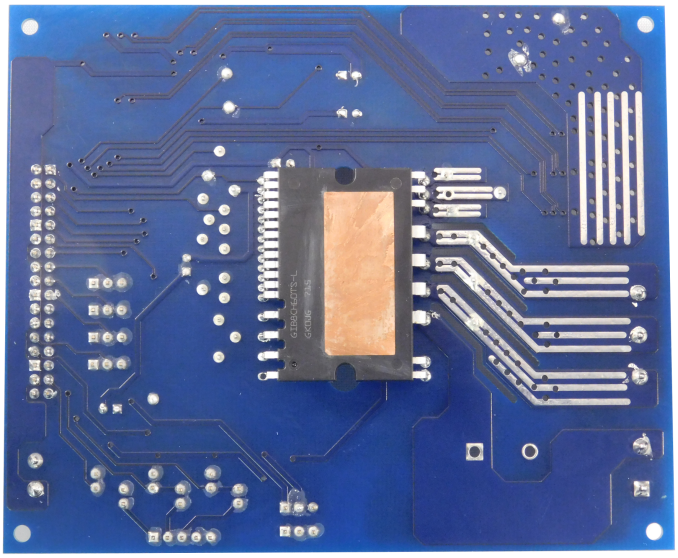
**Figure 1. SLLIMM 2nd series motor control internal demo board (top view)**



# 1 Key features

- Input voltage: 125 - 400 $V_{DC}$
- Nominal power: up to 800 W
- Nominal current: up to 4.8 A
- Input auxiliary voltage: up to 20 V DC
- Motor control connector (32 pins) interfacing with ST MCU boards
- Single- or three-shunt resistors for current sensing (with sensing network)
- Two options for current sensing: external dedicated op-amps or through MCU
- Overcurrent hardware protection
- IPM temperature monitoring and protection
- Hall sensor or encoder input
- IGBT intelligent power module:
  – SLLIMM™ 2$^{nd}$ series IPM (STGIB8CH60TS-L - Full molded package)
- Universal design for further evaluation with bread board and testing pins
- Very compact size

Figure 2. **Motor control board (bottom view) based on SLLIMM™ 2nd series**



# 2 Circuit schematics

The full schematics for the SLLIMM™ 2nd series card for STGIB8CH60TS-L IPM products is shown below. This card consists of an interface circuit (BUS and $V_{CC}$ connectors), bootstrap capacitors, snubber capacitor, short-circuit 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-IPM08B circuit schematic (1 of 6)**

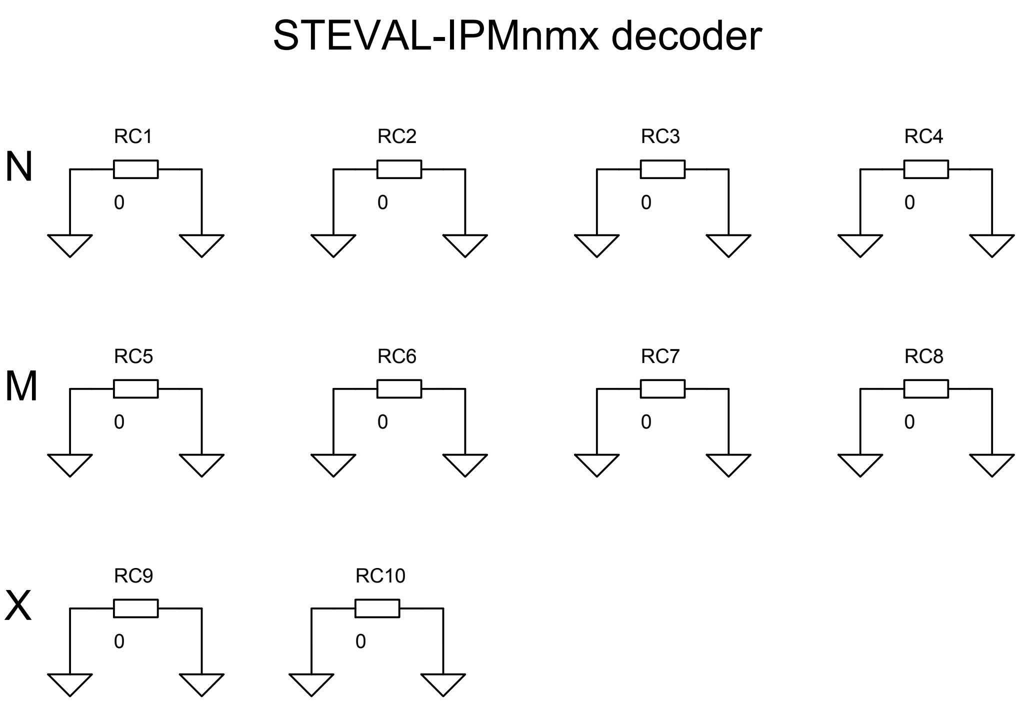


**Figure 4.** **STEVAL-IPM08B circuit schematic (2 of 6)**

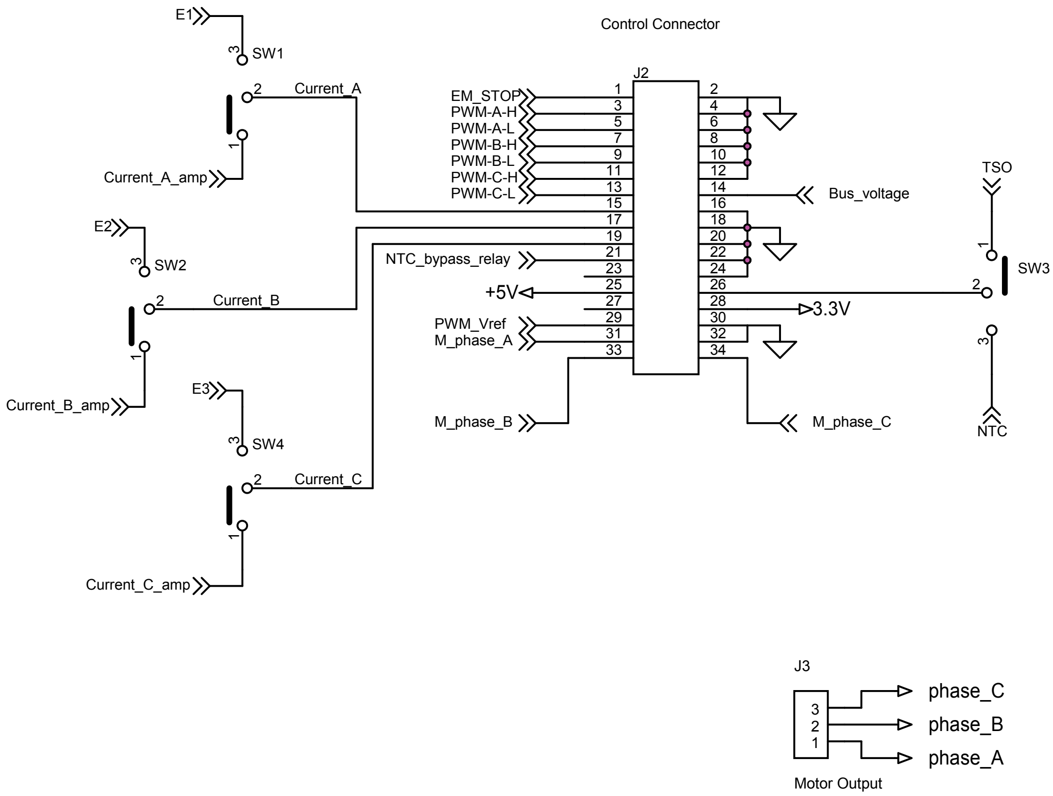


**Figure 5. STEVAL-IPM08B circuit schematic (3 of 6)**

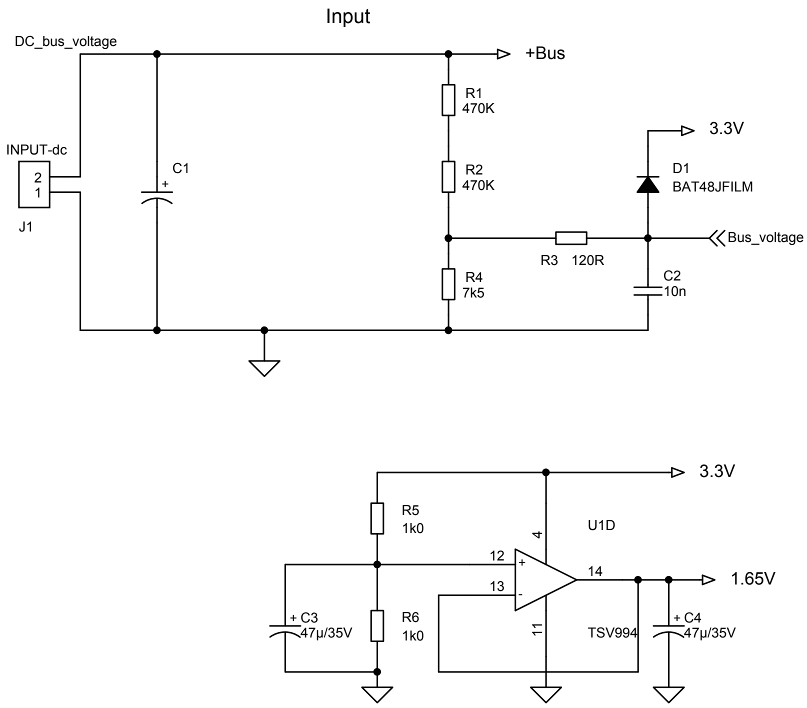


**Figure 6. STEVAL-IPM08B circuit schematic (4 of 6)**

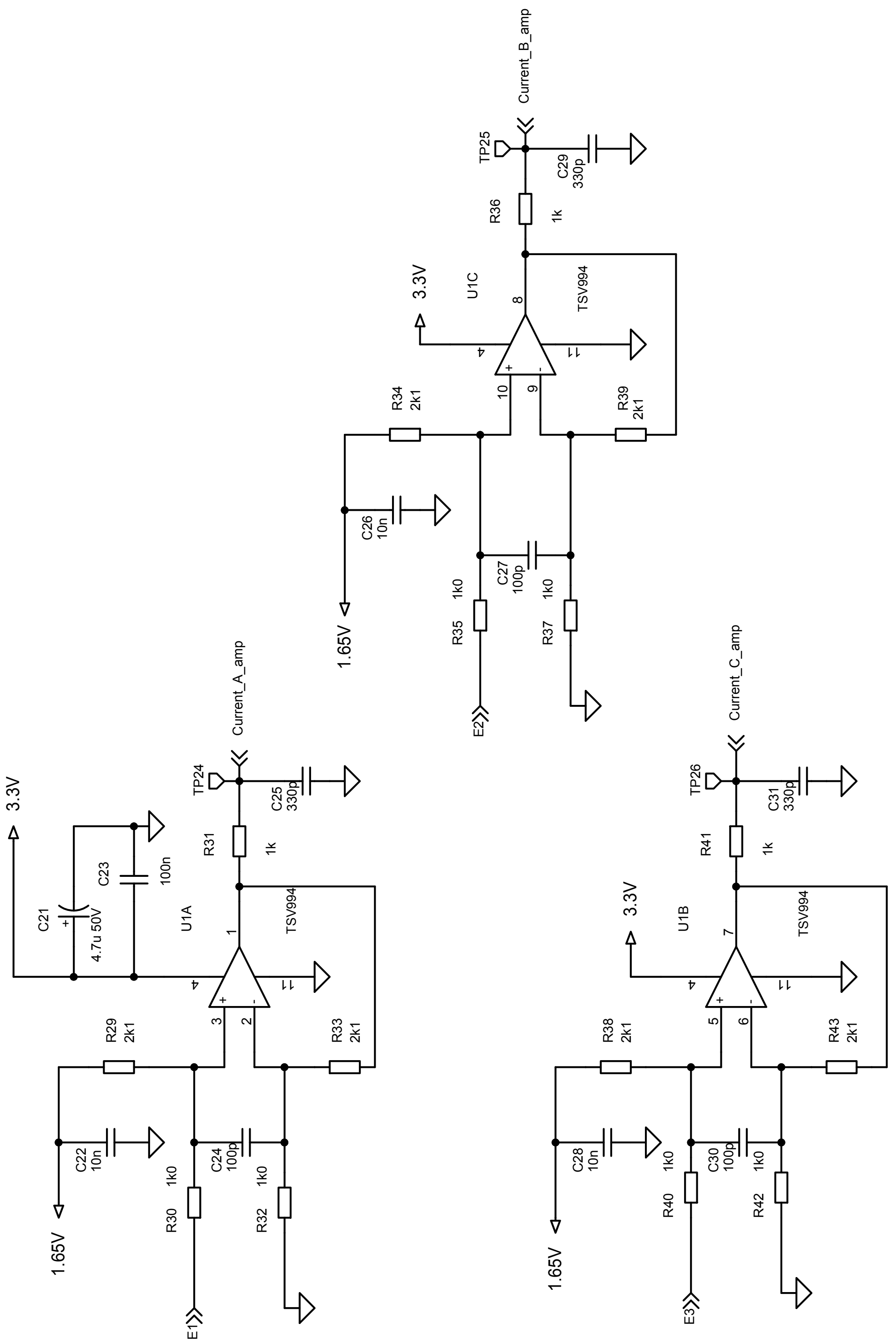


Figure 7. **STEVAL-IPM08B circuit schematic (5 of 6)**

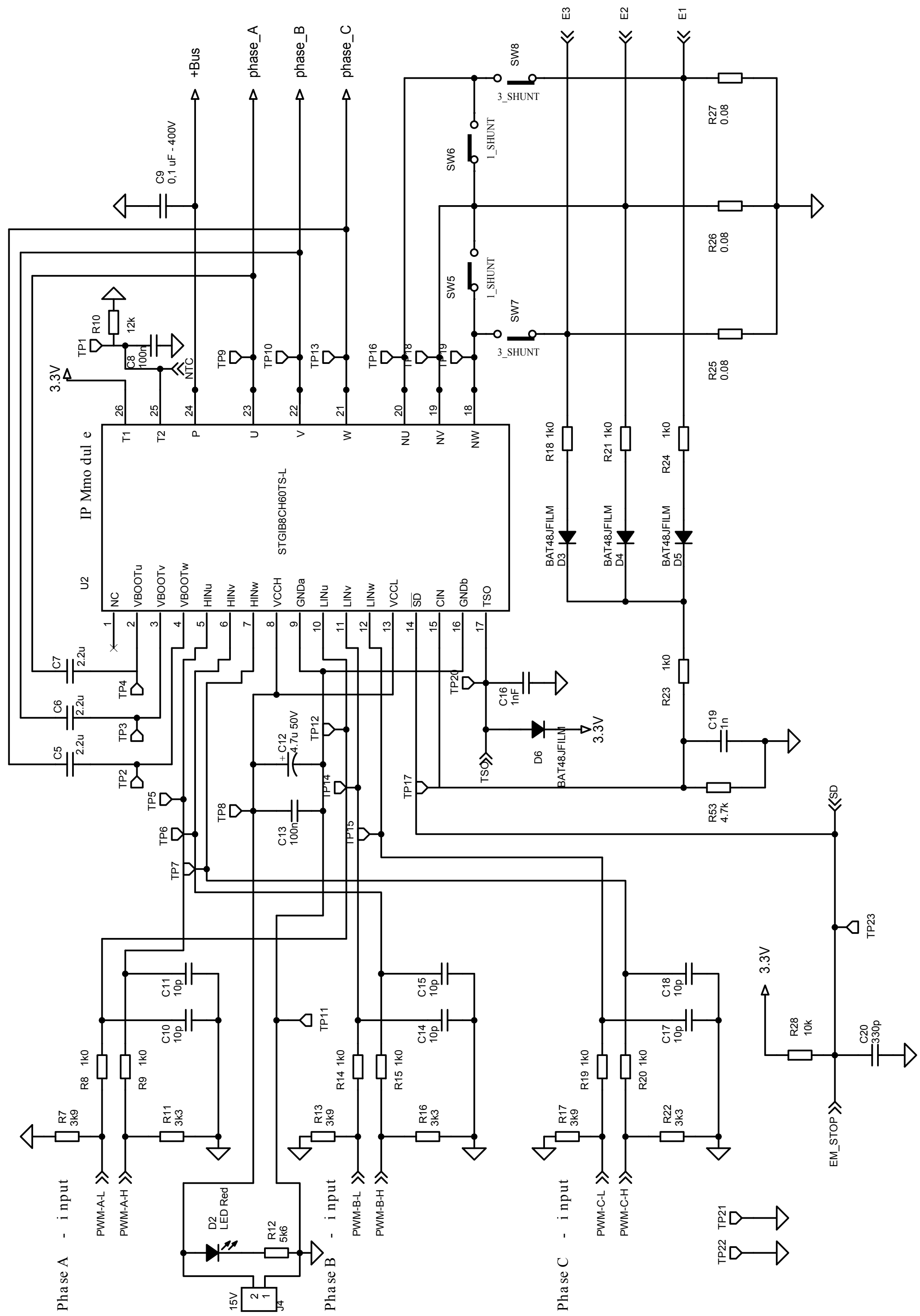
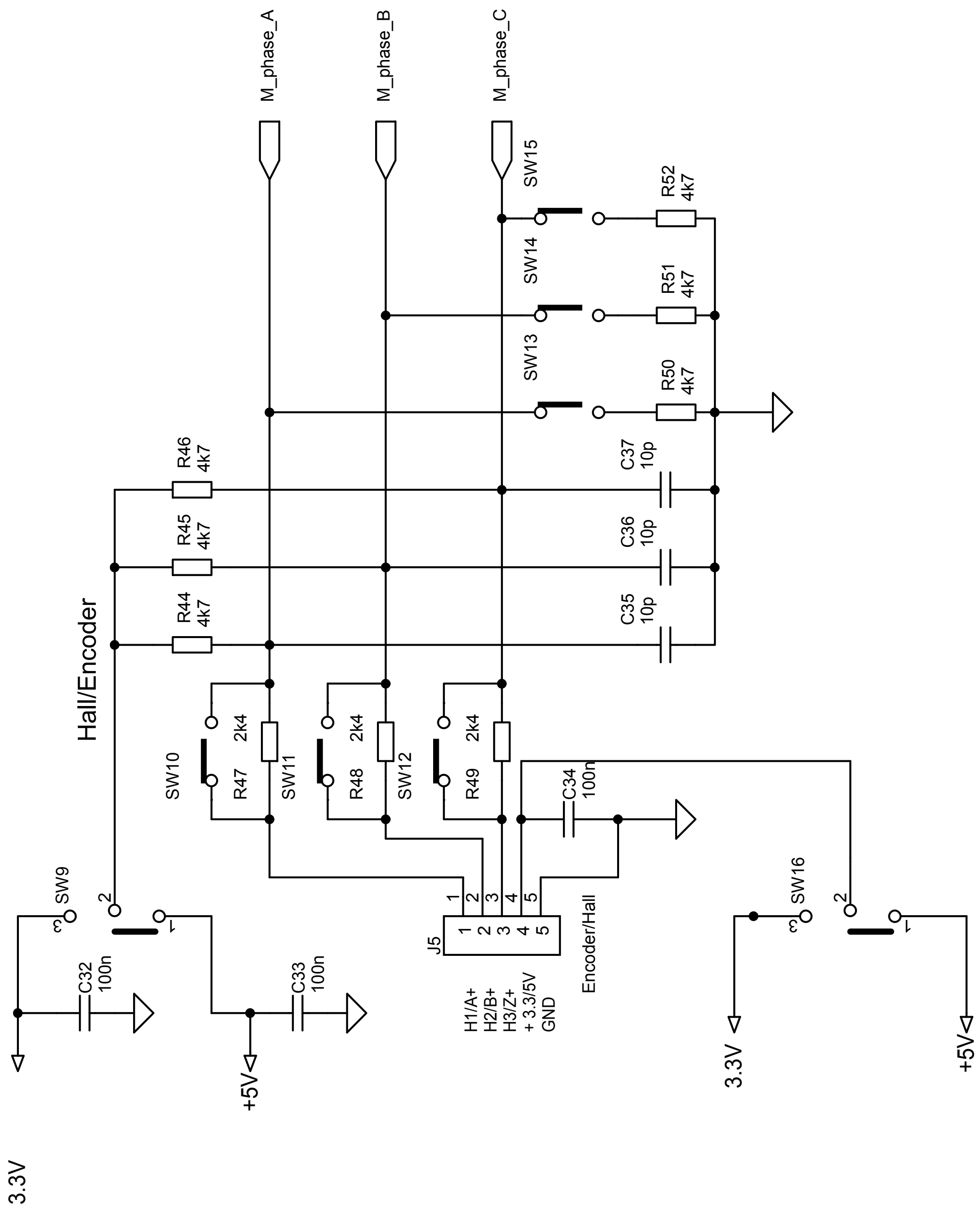


**Figure 8.** STEVAL-IPM08B circuit schematic (6 of 6)



# 3 Main characteristics

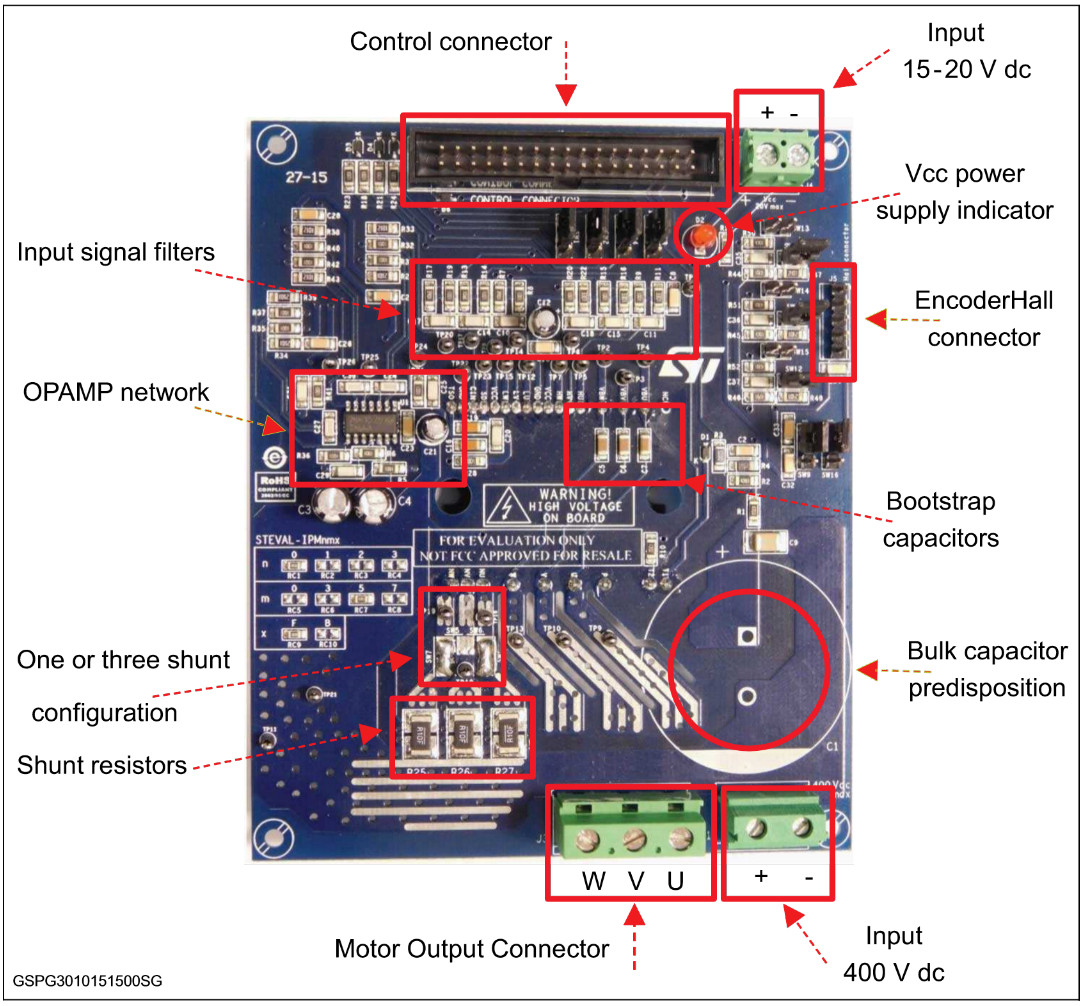
The board is designed for a 125 $V_{DC}$ to 400 $V_{DC}$ supply voltage.

An appropriate bulk capacitor for the power level of the application must be mounted at the dedicated position on the board.

The SLLIMM integrates six IGBT switches with freewheeling diodes and high voltage gate drivers. Thanks to this integrated module, the system offers power inversion in a simple and compact design that requires less PCB area and increases reliability.

The board offers the added flexibility of being able to operate in single- or three-shunt configuration by modifying solder bridge jumper settings (see Section 4.3.5 Single- or three-shunt selection).

**Figure 9. STEVAL-IPM08B architecture**



# 4 Filters and key parameters

## 4.1 Input signals

The input signals (LINx and HINx) to drive the internal IGBTs are active high. A 100 kΩ (typ.) pull-down resistor is built-in for each input signal. To prevent input signal oscillation, an RC filter is added on each input as close as possible to the IPM. The filter is designed using a time constant of 10 ns (1 kΩ and 10 pF).

## 4.2 Bootstrap capacitor

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

A bootstrap method is a simple and cheap solution for supplying the high voltage section. This function is normally accomplished by a high voltage fast recovery diode. The SLLIMM 2$^{nd}$ series family includes a patented integrated structure that replaces the external diode with a high voltage DMOS functioning as a diode with series resistor. An internal charge pump provides the DMOS driving voltage.

The value of the $C_{BOOT}$ capacitor should be calculated according to the application requirements.

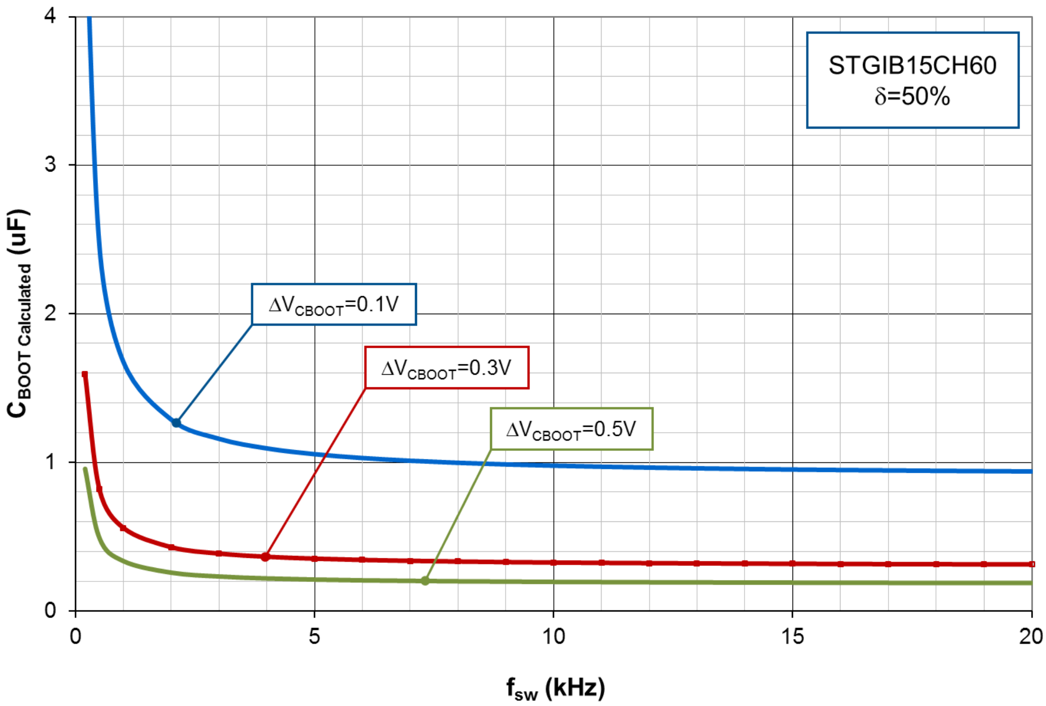
Figure 10. $C_{BOOT}$ graph selection shows the behavior of $C_{BOOT}$ (calculated) versus switching frequency ($f_{sw}$), with different values of $\Delta V_{CBOOT}$ for a continuous sinusoidal modulation and a duty cycle δ = 50%.

*Note: This curve is taken from application note AN4768 (available on www.st.com); calculations are based on the STGIB15CH60 device, which represents the worst case scenario for this kind of calculation.*

The boot capacitor must be two or three times larger than the $C_{BOOT}$ calculated in the graph.

For this design, a value of 2.2 µF was selected.

**Figure 10. $C_{BOOT}$ graph selection**



## 4.3 Overcurrent protection

The SLLIMM 2$^{nd}$ series integrates a comparator for fault sensing purposes. The comparator has an internal voltage reference $V_{REF}$ (510 mV typ.) connected to the inverting input, while the non-inverting input 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 $\overline{SD}$ 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 (3.3 V), a pull up resistor of 10 kΩ (R28) is used to guarantee the right bias and keep the current on the open drain DMOS ($I_{OD}$) below 3mA.

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

A shutdown event can be managed by the MCU; in which case, the SD functions as the input pin.

Conversely, the 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 | Over current event | ≤ 24 µs | 24 µs |
| | | > 24 µs | OC time |
| UVLO | Undervoltage lockout event | ≤ 70 µs | 70 µs |
| | | > 70 µs until VCC_LS exceeds the VCC_LS UV turn on threshold | UVLO time |

1. *typical value ($T_J$ = -40 °C to 125 °C)*
2. *without contribution of RC network on SD*

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 µs (for OC event less than 24 µs).

Figure 11. **SD failure due to overcurrent**

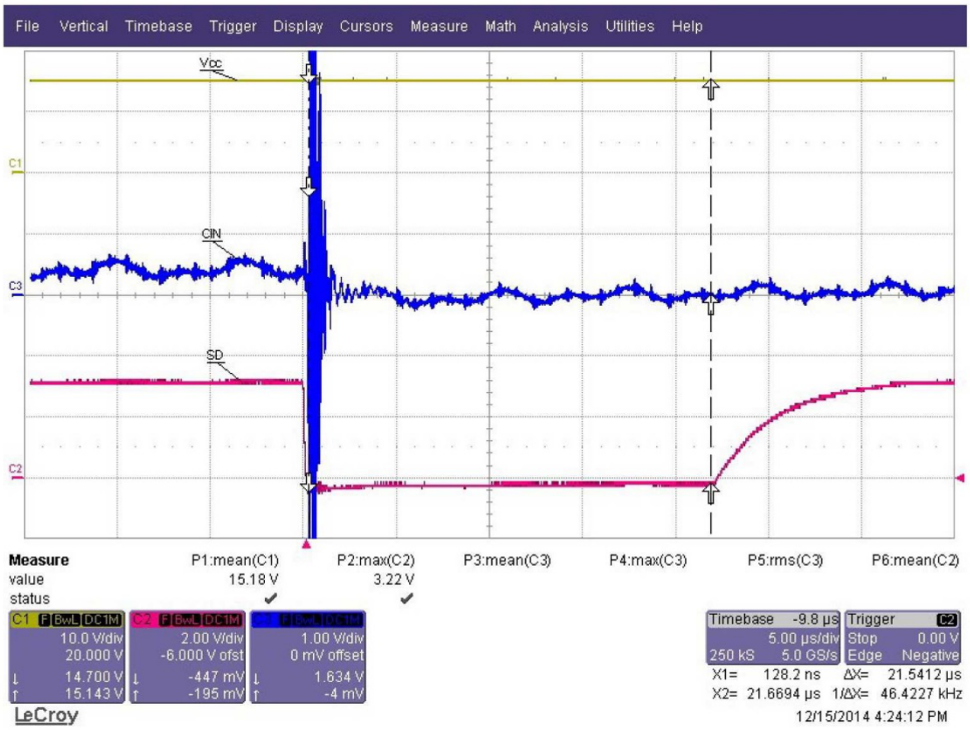



Figure 12. SD failure due to undervoltage (UVLO below 70 µs) shows the shutdown event as the result of an undervoltage condition on the $V_{CC}$ supply. If $V_{CC}$ drops below the undervoltage threshold, the shutdown can stop the application. If the voltage on $V_{CC}$ rises above the $V_{CC}$ on threshold in less than 70 µs, the SD event time is about 70 µs.

Figure 12. **SD failure due to undervoltage (UVLO below 70 µs)**

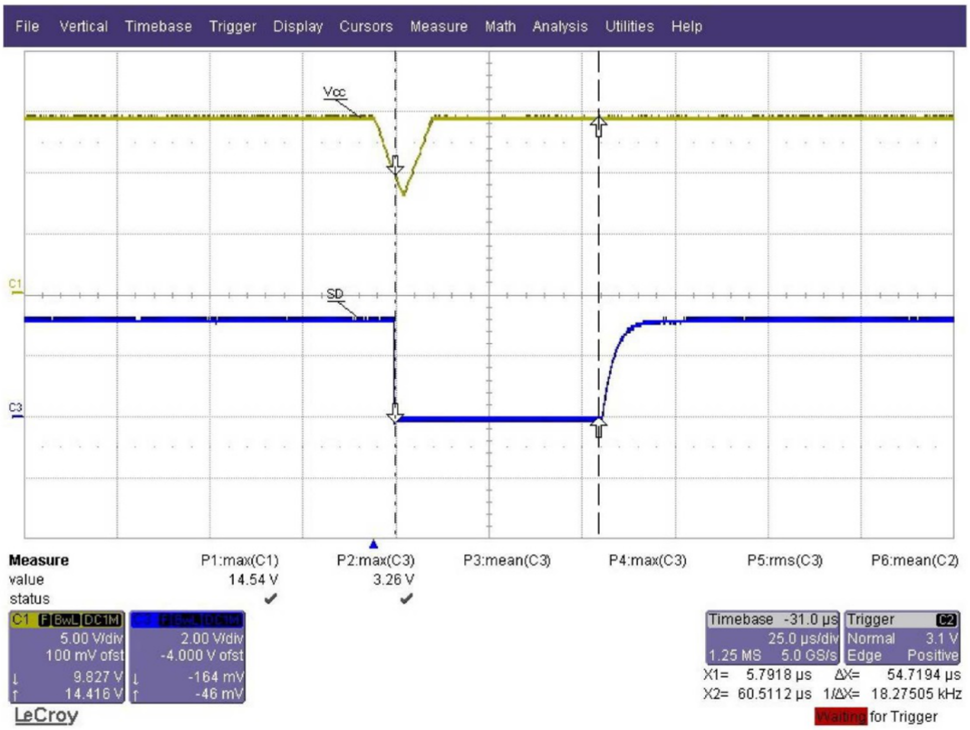
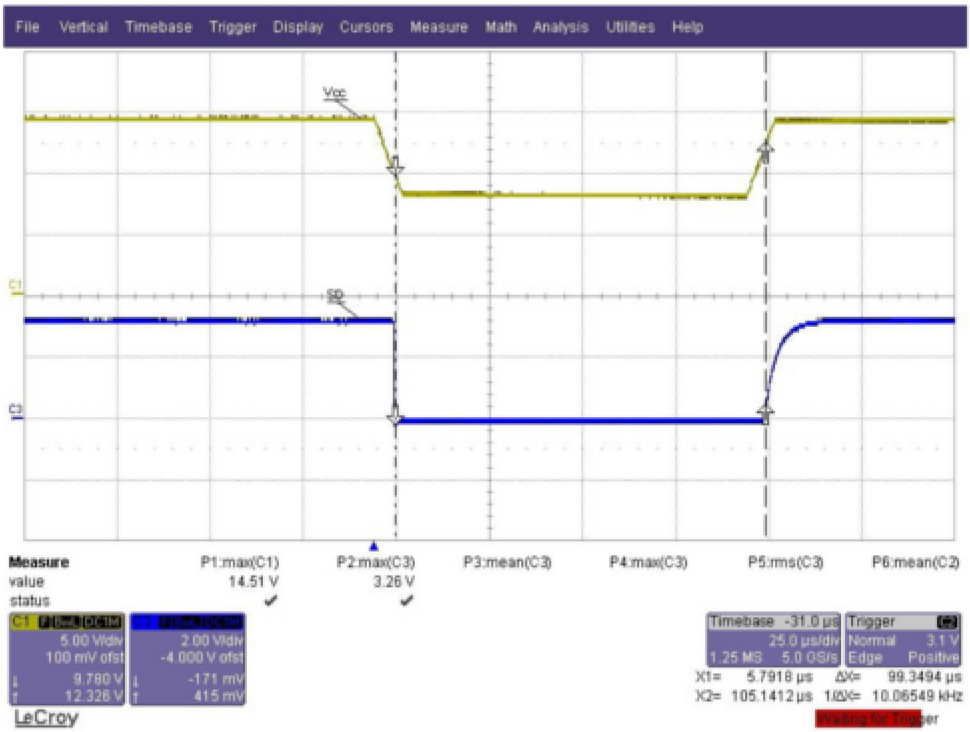



Figure 13. SD failure due to undervoltage (UVLO above 70 µs) shows the shutdown event as the result of an undervoltage condition on the $V_{CC}$ supply. In this case, the drop on $V_{CC}$ is greater than 70 µs. The SD event time is the same as the duration of drop.

Figure 13. **SD failure due to undervoltage (UVLO above 70 µs)**



### 4.3.3 Shunt resistor selection

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

$$R_{SH} = \frac{V_{ref}}{I_{OC}} \tag{1}$$

Where $V_{ref}$ is the internal comparator (CIN) (0.51 V typ.) and $I_{OC}$ is the overcurrent threshold detection level.

The maximum OC protection level should be set to less than the pulsed collector current in the datasheet. In this design, the overcurrent threshold level is fixed at $I_{OC}$ = 10.4 A in order to select a commercial shunt resistor value.

$$R_{SH} = \frac{V_{ref} \cdot \left(\frac{R23 + R53}{R53}\right) + V_F}{I_{OC}} = \frac{0.51 \cdot \left(\frac{1000 + 4700}{4700}\right) + 0.18}{10.4} = 0.077\Omega \tag{2}$$

Where $V_F$ is the voltage drop across diodes D6, D7 and D8.

For the power rating of the shunt resistor, the following parameters must be considered:

- Maximum load current of inverter (85% of $I_{nom\ [Arms]}$): $I_{load(max)}$
- Shunt resistor value at TC = 25 °C
- Power derating ratio of shunt resistor at $T_{SH}$ =100 °C
- Safety margin

The power rating is calculated by the following equation:

$$P_{SH} = \frac{1}{2} \cdot \frac{I^2_{load(\max)} \cdot R_{SH} \cdot margin}{Derating\ gratio} \tag{3}$$

The commercial value chosen was 0.08 Ω to which corresponds an overcurrent level of 10.4 A.

The power rating is:

- $$I_{nom} = 8A \rightarrow I_{nom[rms]} = \frac{I_{nom}}{\sqrt{2}} \rightarrow I_{load(\max)} = 85\,\% \left(I_{nom[rms]}\right) = 4.8\ A_{rms} \tag{4}$$
- Power derating ratio of shunt resistor at TSH = 100 °C: 80% (from datasheetmanufacturer)
- Safety margin: 30%

$$P_{SH} = \frac{1}{2} \cdot \frac{1.2^2 \cdot 0.33 \cdot 1.3}{0.8} = 1.49\,W \tag{5}$$

Considering the commercial value, a 1 W shunt resistor was selected.

Based on the previous equations and conditions, the minimum shunt resistance and power rating is summarized below.

**Table 2. Shunt selection**

| Device | $I_{nom(peak)}$ [A] | $OCP_{(peak)}$ [A] | $I_{load(max)}$ [Arms] | $R_{SHUNT}$ [Ω] | Minimum shunt power rating $P_{SH}$ [W] |
|---|---|---|---|---|---|
| STGIB8CH60TS-L | 8 | 10.4 | 4.8 | 0.08 | 1.49 |

### 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 IGBT turn-off time (hundreds of nanoseconds in total), the total delay time is less than 5 µs of short circuit withstand IGBT 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 14. One-shunt configuration

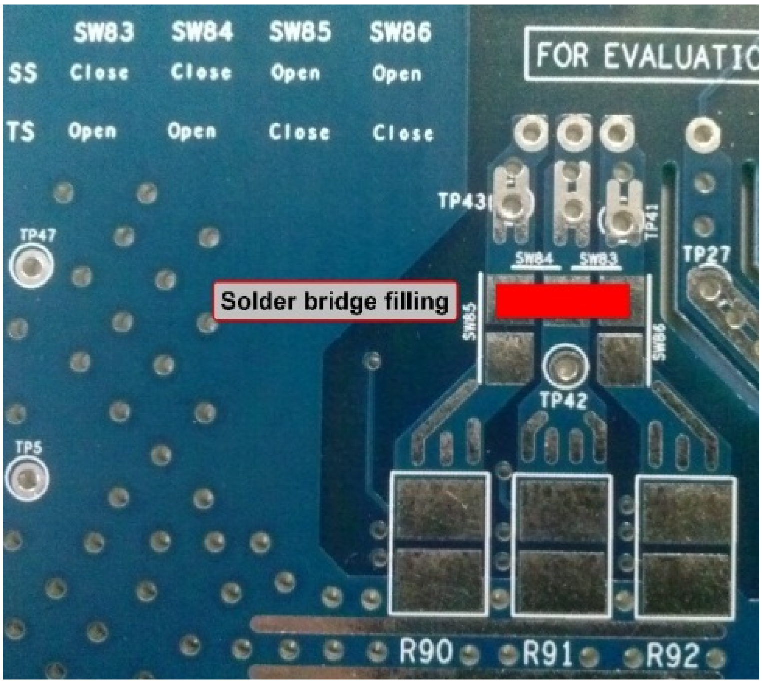
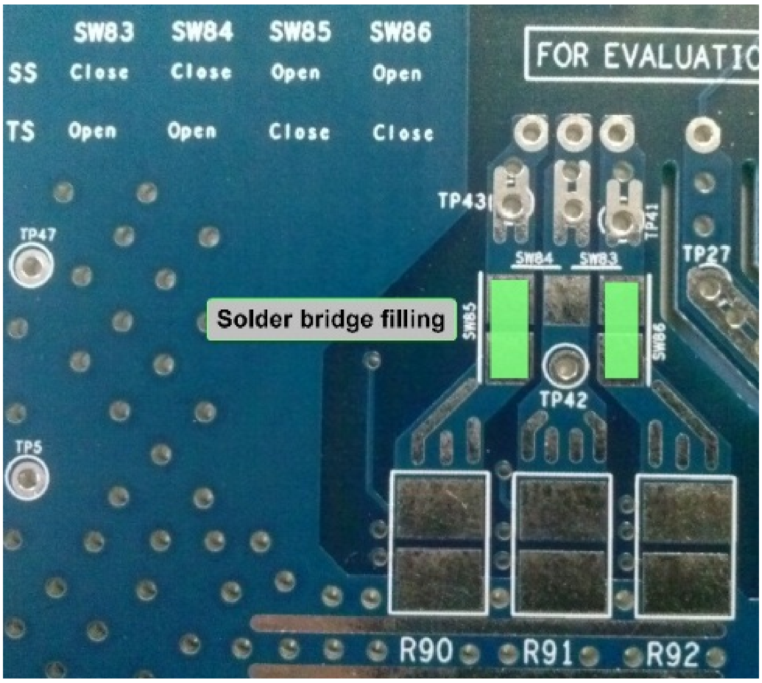



Figure 15. Three-shunt configuration



# 5 Current sensing amplifying network

The STEVAL-IPM08B motor control demonstration 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 whether to send the voltage shunt to the MCU amplified or not amplified.

Single-shunt configuration requires a single op amp so the only voltage sent to the MCU to control the sensing is connected to phase V through SW2.

SW1, SW2, SW3 and SW17 can be configured to select which signals are sent to the microcontroller, as per the following table.

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

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

The operational amplifier TSV994 used in the amplifying networks has a 20 MHz gain bandwidth from a single positive supply of 3.3 V.

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

For the STGIB8CH60TS-L ($I_{OCP}$ = 4.2 A; $R_{SHUNT}$ = 0.08 Ω), 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:

**Equation 5**

$$MaxMeasCurrent = \frac{\Delta V}{r_m} = 10\ A \quad (6)$$

$$r_m = \frac{\Delta V}{MaxMeasCurrent} = \frac{1.65}{10} = 0.165\ \Omega \quad (7)$$

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

$$r_m = R_{SHUNT} \cdot AMP = 0.08 \cdot AMP = 0.165\ \Omega \quad (8)$$

$$AMP = \frac{r_m}{R_{SHUNT}} = \frac{0.165}{0.08} = 2.1 \quad (9)$$

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

$$AMP = \frac{R_c}{R_a} = 2.1 \quad (10)$$

An amplification gain of 2.1 is 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 µs:

$$4 \cdot \tau = 4 \cdot R_e \cdot C_c = 1.5\ \mu s \quad (11)$$

$$C_c = \frac{1.5\ \mu s}{4 \cdot 1000} = 375\ pF \left(330\ pF\ selected\right) \quad (12)$$

**Table 4. Amplifying networks**

| Phase | Amplifying network | | | | RC filter | |
|---|---|---|---|---|---|---|
| | Ra | Rb | Rc | Rd | Re | Cc |
| 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)

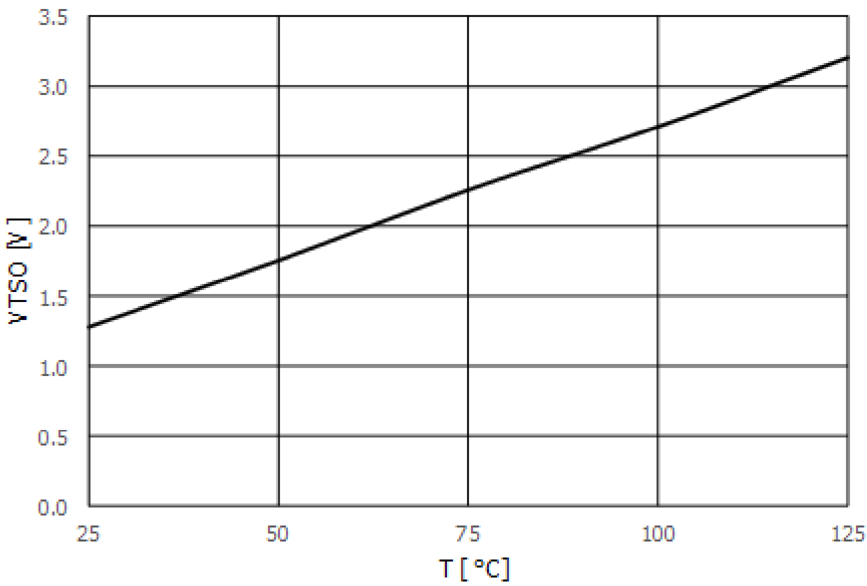
A voltage proportional to the temperature is available on the TSO pin (17) and easily measurable on the TP20 test pin.

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 16. Thermal sensor voltage vs temperature**



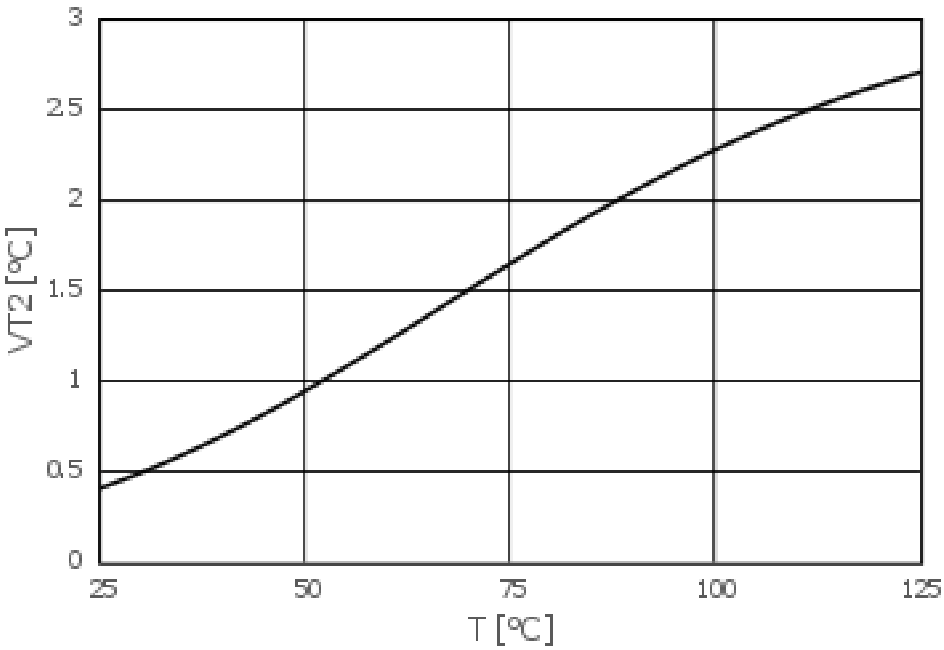

## 6.2 NTC Thermistor

The embedded thermistor (85 kΩ at 25 °C) in the IPM is connected between pins T1 and T2 (26, 25).

A12 kΩ pull up 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 17.** 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 motors (PMSM): STM32 PMSM FOC SDK for this STEVAL-IPM08B.

**Table 5. ST motor control workbench GUI parameters - STEVAL-IPM08B**

| Block | Parameter | Value |
|---|---|---|
| Over current protection | Comparator threshold | $$V_{ref} \cdot \left( \frac{R23 + R53}{R53} \right) + V_F = 0.83V \quad (13)$$ |
| | Overcurrent network offset | 0 |
| | Overcurrent network gain | 0.1 V/A |
| 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 | 0.08 Ω |
| | 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**

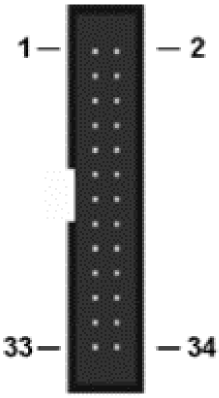
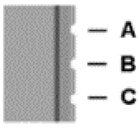
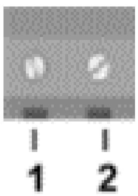
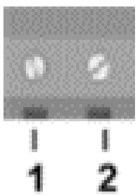
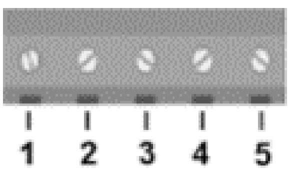
<table>
<tr><th>Connector</th><th>Reference</th><th colspan="2">Description / pinout</th></tr>
<tr><td rowspan="17">J2</td><td rowspan="17"></td><td colspan="2">Motor control connector</td></tr>
<tr><td>1 - emergency stop</td><td>2 - GND</td></tr>
<tr><td>3 - PWM-1H</td><td>4 - GND</td></tr>
<tr><td>5 - PWM-1L</td><td>6 - GND</td></tr>
<tr><td>7 - PWM-2H</td><td>8 - GND</td></tr>
<tr><td>9 - PWM-2L</td><td>10 - GND</td></tr>
<tr><td>11 - PWM-3H</td><td>12 - GND</td></tr>
<tr><td>13 - PWM-3L</td><td>14 - HV bus voltage</td></tr>
<tr><td>15 - current phase A</td><td>16 - GND</td></tr>
<tr><td>17 - current phase B</td><td>18 - GND</td></tr>
<tr><td>19 - current phase C</td><td>20 - GND</td></tr>
<tr><td>21 - NTC bypass relay</td><td>22 - GND</td></tr>
<tr><td>23 - dissipative brake PWM</td><td>24 - GND</td></tr>
<tr><td>25 - +V power</td><td>26 - heat sink temperature</td></tr>
<tr><td>27- PFC sync.</td><td>28 - VDD_m</td></tr>
<tr><td>29 - PWM VREF</td><td>30 - GND</td></tr>
<tr><td>31 - measure phase A<br>33 - measure phase B</td><td>32 - GND<br>34 - measure phase C</td></tr>
<tr><td>J3</td><td></td><td colspan="2">Motor connector<br>• phase A<br>• phase B<br>• phase C</td></tr>
<tr><td>J4</td><td></td><td colspan="2">VCC supply (20 VDC max)<br>• positive<br>• negative</td></tr>
<tr><td>J7</td><td></td><td colspan="2">Supply connector (DC – 125V to 400 V)<br>1. + (positive terminal)<br>2. - (negative terminal)</td></tr>
<tr><td>J9</td><td></td><td colspan="2">Hall sensors / encoder input connector<br>1. Hall sensors input 1 / encoder A+<br>2. Hall sensors input 2 / encoder B+<br>3. Hall sensors input 3 / encoder Z+<br>4. 3.3 or 5 Vdc<br>5. GND</td></tr>
</table>

**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, SW6<br>SW7, SW8 | To choose one-shunt or three-shunt configuration.<br>(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) |

| Test Pin | Description |
|---|---|
| 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 Bill of materials

The components used to build the evaluation board are listed below. The majority of the active components used are available from STMicroelectronics.

**Table 9. Bill of materials**

| Item | Qty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 1 | 4 | C2,C22,C26,C28 | 10 nF 50 V ±10% | Capacitor SMD 1206 | Any | |
| 2 | 9 | C10, C11, C14, C15, C17, C18, C35, C36, C37 | 10 pF 100 V ±10% | Capacitor SMD 1206 | Any | |
| 3 | 4 | C20, C25, C29, C31 | 330 pF 50 V ±10% | Capacitor SMD 1206 | Any | |
| 4 | 3 | C5, C6, C7 | 2.2 µF 25 V ±10% | Capacitor SMD 1206 | Any | |
| 5 | 6 | C8, C13, C23, C32, C33, C34 | 100 nF 50 V ±10% | Capacitor SMD 1206 | Any | |
| 6 | 2 | C12, C21 | 4.7 µF 50 V ±10% | Elyt. capacitor, 4x4 | Any | |
| 7 | 2 | C19, C16 | 1 nF 50 V ±10% | Capacitor SMD 1206 | Any | |
| 8 | 1 | C9 | 0.1 µF 630 V ±10% | Capacitor SMD 1812 | Any | |
| 9 | 3 | C24, C27, C30 | 100 pF 100 V ±10% | Capacitor SMD 1206 | Any | |
| 10 | 2 | C3, C4 | 47 µF 50 V ±10% | Elyt. capacitor, 4x4 | Any | |
| 11 | 5 | D1, D3, D4, D5, D6 | | Schottky Diode, SOD323 | ST | BAT48J |
| 12 | 1 | D2 | RED LED | LED 3 mm, 2 mA, universal | Any | |
| 13 | 1 | J2 | Connector | Connector 34-pins | Any | |
| 14 | 1 | J3 | Connector 400 V | Connector - 7 mm - 3 pole | Any | |
| 15 | 1 | J4 | Connector 50 V | Connector - 5 mm - 2 pole | Any | |
| 16 | 1 | J1 | Connector 300 V | Connector - 7 mm - 2 pole | Any | |
| 17 | 1 | J5 | Connector 63 V | Five pins of pin header | Any | |
| 18 | 2 | R1, R2 | 470 kΩ 400 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 19 | 1 | R4 | 7.5 kΩ 400 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 20 | 1 | R3 | 120 Ω 400 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 21 | 3 | R7, R13, R17 | 3.9 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 22 | 21 | R5, R6, R8, R9, R14, R15, R19, R20, R23, R30, R32, R31, R18, R21, R24, R36, R35, R41, R42, R40, R37 | 1 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |

| Item | Qty | Ref. | Part / Value | Description | Manufacturer | Order code |
|---|---|---|---|---|---|---|
| 23 | 3 | R11, R16, R22 | 3.3 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 24 | 1 | R28 | 10 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 25 | 1 | R10 | 12 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 26 | 6 | R29, R33, R34, R38, R39, R43 | 2.1 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 27 | 1 | R12 | 5.6 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 28 | 3 | R25, R26, R27 | 0.08 Ω | Resistor SMD 2512 | Vishay | WSL2816R0800FEH |
| 29 | 6 | R44, R45, R46, R50, R51, R52, R53 | 4.7 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 30 | 3 | R47, R48, R49 | 2.4 kΩ 25 V 1/8 ±1% | Resistor SMD 1206 | Any | |
| 31 | 6 | SW1, SW2, SW3, SW4, SW9, SW16 | Jumper 2.54 | Three pins of pin header | Any | |
| 32 | 6 | SW10, SW11, SW12, SW13, SW14, SW15 | Jumper 2.54 | Two pins of pin header | Any | |
| 33 | 12 | | 2.54 mm | low profile connector | Any | |
| 34 | 2 | SW7, SW8 | Solder bridge | | NA | |
| 35 | 2 | SW5, SW6 | open | | Any | |
| 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 1 mm | Test pin | Any | |
| 37 | 1 | U1 | 20 MHz GBP | Rail-to-rail input/ output operational amplifiers, SO14 | ST | TSV994 |
| 38 | 1 | U2 | 3-phase inverter, 12 A, 600 V short-circuit rugged IGBTs | SLLIMM 2nd series IPM, Full molded package | ST | STGIB15CH60TS-L |
| 39 | 3 | RC2,RC5,RC10 | 0 Ω | Resistor, SMD 0805 | Any | |
| 40 | 7 | RC1,RC3,RC4,RC6, RC7,RC8,RC9 | NOT MOUNTED | NOT MOUNTED | Any | |
| 41 | 9 | to close switch for: SW1, SW2, SW3, SW4, SW9, SW10, SW11, SW12, SW16 | | | Any | |

# 10 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 other hand, 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.

## 10.1 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 18. Silk screen and etch - top side

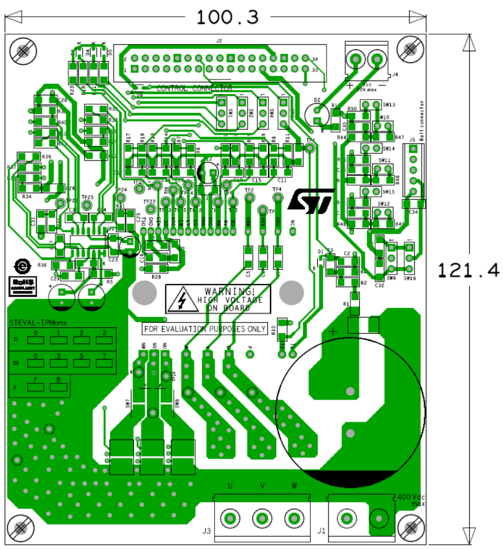
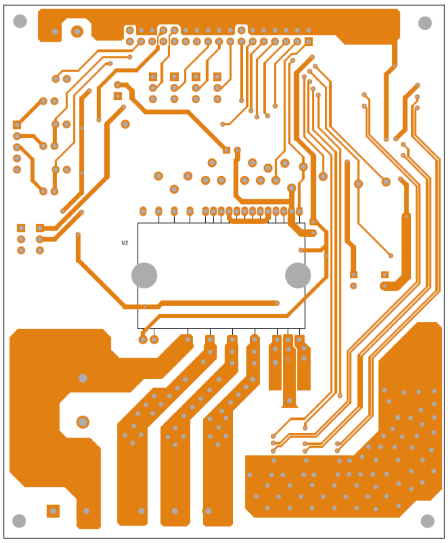


Figure 19. Silk screen and etch - bottom side



# 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 bus supply voltage, it is advisable to use an adequate bulk capacity. For general motor control applications, an electrolytic capacitor of at least 100 μF is suggested.
- Similarly, the PCB does not come with a heat sink. In case of need, place an heat sink on top of the PCB with thermal conductive foil and screws. $R_{TH}$ is an important factor for good thermal performance and depends on certain factors such as current phase, switching frequency, power factor and ambient temperature.
- 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

**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).*

# 13 References

All of the following reference material is freely available on www.st.com

1. STGIB8CH60TS-L datasheet
2. TSV994 datasheet
3. STTH15R06 datasheet
4. User manual UM1052 *STM32F PMSM single/dual FOC SDK v4.3*
5. Application note AN4076 *Two or three shunt resistor based current sensing circuit design in 3-phase inverters*

# Revision history

Table 10. **Document revision history**

| Date | Version | Changes |
|---|---|---|
| 09-Sep-2017 | 1 | Initial release. |
| 04-Apr-2018 | 2 | Updated title. |
| 18-Sep-2019 | 3 | Updated Section 2.1 Schematic diagrams |

# Contents

# List of tables

# List of figures