

# EVAL-IMI111T user guide

## iMOTION™ MADK starter kit for IMI111T IPMs

### About this document

#### Scope and purpose

This user guide provides an overview of the EVAL-IMI111T evaluation board including its main features, key technical data, pin assignments, and mechanical dimensions.

EVAL-IMI111T is a full featured starter kit that includes the IMI111T iMOTION™ IPMs. It provides a fully-integrated, turnkey, high voltage motor drive solution designed for high performance and high efficiency permanent magnet synchronous motor (PMSM)/ brushless direct current motor (BLDC) motor drive applications such as fans, pumps, and compressors. EVAL-IMI111T also comprises other necessary circuitry required for out-of-the-box evaluation of IMI111T iMOTION™ IPMs, such as rectifier and EMI filter stage, as well as an isolated debugger section with USB connection to the PC.

The EVAL-IMI111T starter kit was developed to support customers during their first steps in designing applications with IMI111T iMOTION™ IPMs.

The available variants of the IMI111T starter kit are listed in Table 1.

**Table 1** EVAL-IMI111T starter kit variants

| Sales name       | Orderable part number | iMOTION™ device | DC rating | V <sub>CE(sat)</sub> Typ at 25°C |
|------------------|-----------------------|-----------------|-----------|----------------------------------|
| EVAL-IMI111T-026 | EVALIMI111T026TOBO1   | IMI111T-026H    | 600V / 2A | 1.5 V                            |
| EVAL-IMI111T-046 | EVALIMI111T046TOBO1   | IMI111T-046H    | 600V / 4A | 1.4 V                            |

All the information provided in this user guide applies to both versions of the starter kit unless explicitly stated.

#### Intended audience

This user guide is intended for all technical specialists familiar with motor control and high power electronic converters. The EVAL-IMI111T evaluation board is intended to be used under laboratory conditions only by trained specialists.

#### Evaluation board

This board is used during design in for evaluation and measurement of characteristics, and proof of data sheet specifications.

*Note: PCB and auxiliary circuits are NOT optimized for final customer design.*

### Important notice

### Important notice

**“Evaluation Boards and Reference Boards” shall mean products embedded on a printed circuit board (PCB) for demonstration and/or evaluation purposes, which include, without limitation, demonstration, reference and evaluation boards, kits and design (collectively referred to as “Reference Board”).**

**Environmental conditions have been considered in the design of the Evaluation Boards and Reference Boards provided by Infineon Technologies. The design of the Evaluation Boards and Reference Boards has been tested by Infineon Technologies only as described in this document. The design is not qualified in terms of safety requirements, manufacturing and operation over the entire operating temperature range or lifetime.**

**The Evaluation Boards and Reference Boards provided by Infineon Technologies are subject to functional testing only under typical load conditions. Evaluation Boards and Reference Boards are not subject to the same procedures as regular products regarding returned material analysis (RMA), process change notification (PCN) and product discontinuation (PD).**

**Evaluation Boards and Reference Boards are not commercialized products, and are solely intended for evaluation and testing purposes. In particular, they shall not be used for reliability testing or production. The Evaluation Boards and Reference Boards may therefore not comply with CE or similar standards (including but not limited to the EMC Directive 2004/EC/108 and the EMC Act) and may not fulfill other requirements of the country in which they are operated by the customer. The customer shall ensure that all Evaluation Boards and Reference Boards will be handled in a way which is compliant with the relevant requirements and standards of the country in which they are operated.**

**The Evaluation Boards and Reference Boards as well as the information provided in this document are addressed only to qualified and skilled technical staff, for laboratory usage, and shall be used and managed according to the terms and conditions set forth in this document and in other related documentation supplied with the respective Evaluation Board or Reference Board.**

**It is the responsibility of the customer’s technical departments to evaluate the suitability of the Evaluation Boards and Reference Boards for the intended application, and to evaluate the completeness and correctness of the information provided in this document with respect to such application.**

**The customer is obliged to ensure that the use of the Evaluation Boards and Reference Boards does not cause any harm to persons or third party property.**

**The Evaluation Boards and Reference Boards and any information in this document is provided "as is" and Infineon Technologies disclaims any warranties, express or implied, including but not limited to warranties of non-infringement of third party rights and implied warranties of fitness for any purpose, or for merchantability.**

**Infineon Technologies shall not be responsible for any damages resulting from the use of the Evaluation Boards and Reference Boards and/or from any information provided in this document. The customer is obliged to defend, indemnify and hold Infineon Technologies harmless from and against any claims or damages arising out of or resulting from any use thereof.**

**Infineon Technologies reserves the right to modify this document and/or any information provided herein at any time without further notice.**

## Safety precautions

## Safety precautions

Note: Please note the following warnings regarding the hazards associated with development systems.

**Table 2** Safety precautions

|   |   |
|---|---|
|    | <b>Warning:</b> The DC link potential of this board is up to 1000 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.  |
|    | <b>Warning:</b> The evaluation or reference board contains DC bus capacitors which take time to discharge after removal of the main supply. Before working on the drive system, wait five minutes for capacitors to discharge to safe voltage levels. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.                                |
|    | <b>Warning:</b> The evaluation or reference board is connected to the grid input during testing. Hence, high-voltage differential probes must be used when measuring voltage waveforms by oscilloscope. Failure to do so may result in personal injury or death. Darkened display LEDs are not an indication that capacitors have discharged to safe voltage levels.  |
|   | <b>Warning:</b> Remove or disconnect power from the drive before you disconnect or reconnect wires, or perform maintenance work. Wait five minutes after removing power to discharge the bus capacitors. Do not attempt to service the drive until the bus capacitors have discharged to zero. Failure to do so may result in personal injury or death.   |
|  | <b>Caution:</b> The heat sink and device surfaces of the evaluation or reference board may become hot during testing. Hence, necessary precautions are required while handling the board. Failure to comply may cause injury.   |
|  | <b>Caution:</b> Only personnel familiar with the drive, power electronics and associated machinery should plan, install, commission and subsequently service the system. Failure to comply may result in personal injury and/or equipment damage.   |
|  | <b>Caution:</b> The evaluation or reference board contains parts and assemblies sensitive to electrostatic discharge (ESD). Electrostatic control precautions are required when installing, testing, servicing or repairing the assembly. Component damage may result if ESD control procedures are not followed. If you are not familiar with electrostatic control procedures, refer to the applicable ESD protection handbooks and guidelines. |
|  | <b>Caution:</b> A drive that is incorrectly applied or installed can lead to component damage or reduction in product lifetime. Wiring or application errors such as undersizing the motor, supplying an incorrect or inadequate AC supply, or excessive ambient temperatures may result in system malfunction.   |
|  | <b>Caution:</b> The evaluation or reference board is shipped with packing materials that need to be removed prior to installation. Failure to remove all packing materials that are unnecessary for system installation may result in overheating or abnormal operating conditions.   |

## **Table of contents**

|   |           |
|---|-----------|
| <b>About this document.....</b>                                     | <b>1</b>  |
| <b>Important notice .....</b>                                       | <b>2</b>  |
| <b>Safety precautions.....</b>                                      | <b>3</b>  |
| <b>Table of contents.....</b>                                       | <b>4</b>  |
| <b>1 Introduction .....</b>   | <b>5</b>  |
| <b>2 Main features.....</b>   | <b>6</b>  |
| <b>3 Pin assignments.....</b>                                       | <b>10</b> |
| <b>4 System performance .....</b>                                   | <b>13</b> |
| 4.1 DC-link voltage measurement .....                               | 14        |
| 4.2 EMI filter.....   | 15        |
| 4.3 Inverter section using iMOTION™ IPM .....                       | 15        |
| 4.4 Auxiliary power supply .....                                    | 16        |
| 4.5 Current measurement shift stage and overcurrent threshold ..... | 16        |
| <b>5 Thermal characterization.....</b>                              | <b>18</b> |
| 5.1 Thermal characteristic .....                                    | 20        |
| 5.2 Thermal PCB design .....  | 21        |
| <b>6 Thermal protection .....</b>                                   | <b>22</b> |
| <b>7 Getting started with EVAL-IMI111T .....</b>                    | <b>25</b> |
| 7.1 Hardware connection.....  | 25        |
| 7.2 Getting started with iMOTION™ .....                             | 26        |
| 7.3 UART function switching.....                                    | 27        |
| <b>8 PCB layout.....</b>  | <b>28</b> |
| <b>9 Application diagram .....</b>                                  | <b>31</b> |
| 9.1 Application diagram.....  | 31        |
| <b>10 Bill of materials.....</b>                                    | <b>32</b> |
| <b>11 References and appendices .....</b>                           | <b>35</b> |
| 11.1 Abbreviations and definitions.....                             | 35        |
| 11.2 Additional information.....                                    | 35        |
| 11.3 References .....   | 35        |
| <b>12 Revision history .....</b>                                    | <b>36</b> |

## Introduction

### 1 Introduction

The EVAL-IMI111T starter kit provides an easy-to-use motor drive solution based on Infineon's IMI111T iMOTION™ IPMs. The board is equipped with all assembly groups for sensor-less field-oriented control (FOC). It contains a single phase AC-connector, an EMI filter, a rectifier, and a 3-phase output for connecting the motor. The power stage also contains source shunt for current sensing and a voltage divider for measuring the DC-link voltage.

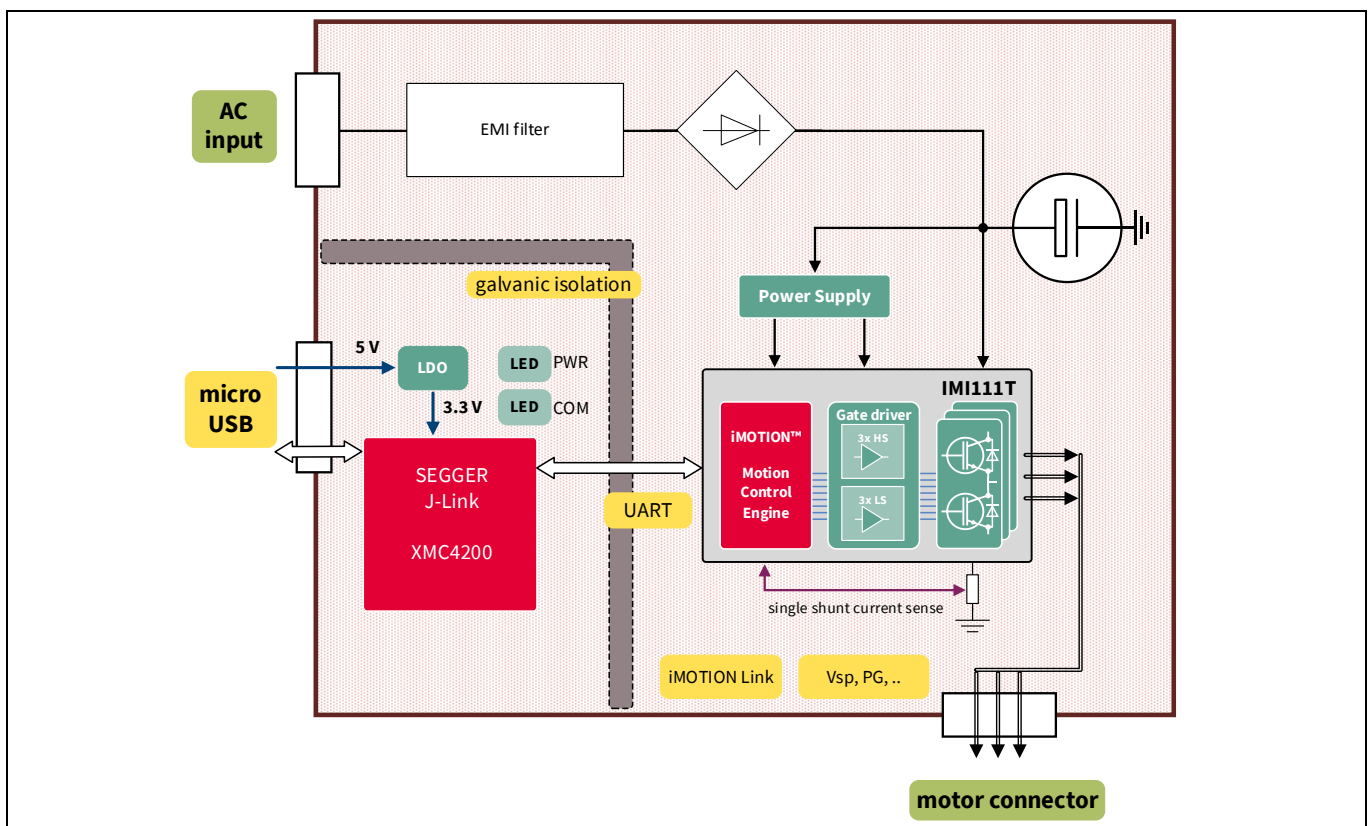
Features of this board are described in Chapter 2 of this user guide. The other chapters provide information to help users copy, modify, and qualify the design for production according to their specific requirements.

Environmental conditions were considered in the design of the EVAL-IMI111T. The design was tested as described in this document but it is not qualified with regard to safety requirements or manufacturing and operating over the whole operating temperature range or lifetime. The boards provided by Infineon are only subject to functional testing.

Evaluation boards are not subject to the same procedures as regular products with regard to returned material analysis (RMA), process change notification (PCN), and product discontinuation (PD). Evaluation boards are intended to be used under laboratory conditions and only by trained specialists.

The iMOTION™ Motion Control Engine (MCE) integrated into IMI111T devices, together with the gate driver and six IGBTs offers a complete motor drive system in a compact DSO22 surface mount package, minimizing the external components count and PCB area.

The block diagram of EVAL-IMI111T is shown in Figure 1.



**Figure 1** Block diagram of EVAL-IMI111T

## Main features

## 2 Main features

EVAL-IMI111T starter kits are intended for evaluating the IMI111T series of iMOTION™ iMOTION™ IPMs. The main features [1] of IMI111T series are:

- Motion Control Engine (MCE) as ready-to-use controller solution for variable speed drives
- Field oriented control (FOC) for permanent magnet synchronous motor (PMSM)
- Space vector pulse width modulation (SVPWM) with sinusoidal commutation and integrated protection features
- Single-shunt current sensing through direct interface
- Sensor-less operation
- Integrated analog comparators for overcurrent protection
- Overvoltage and undervoltage protection
- Rotor lock protection
- Built-in temperature sensor (Overtemperature protection)
- Undervoltage lockout
- Integrated minimum deadtime
- Shoot-through prevention
- Two different power IGBT options: 2 A/600 V, 4 A/600 V
- Two different supply voltage options for controller: 3.3 V 5 V
- 15 V supply voltage for gate driver
- Integrated bootstrap diode structure
- Flexible host interface options for speed commands: UART, SPI, PWM, or analog signal
- Class B pre-certification for MCE 2.0 firmware
- Isolation 1500 V<sub>RMS</sub> 1 min
- Very compact DSO22 package

The main characteristics of the evaluation board are:

- Nominal input voltage 110V<sub>AC</sub> – 230V<sub>AC</sub>
- Onboard EMI filter
- Single-shunt current sensing configuration
- Voltage divider for DC-link voltage sensing
- Measurement test points compatible with standard oscilloscope probes
- Onboard debugger with 1 kV isolation for isolated communication to a PC via USB
- NTC to reduce inrush current
- PCB dimensions: 79.6 mm x 89.6 mm, 2 layers, 2 oz copper
- RoHS compliant

**Main features**

Table 3 lists all the important specifications of the EVAL-IMI111T evaluation board.

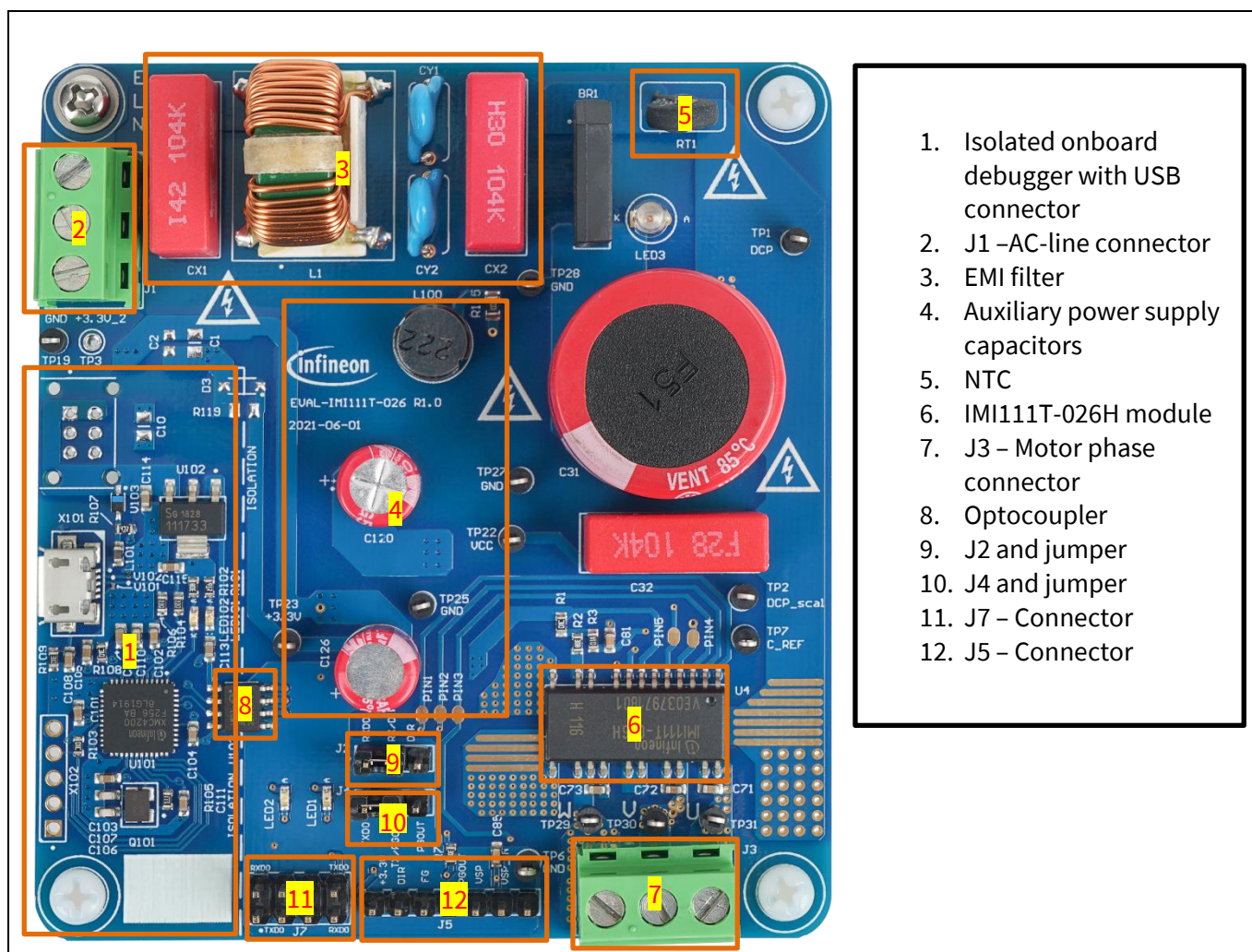
**Table 3 EVAL-IMI111T specifications**

| Parameters               | Device           | Values                     | Conditions   |
|--------------------------|------------------|----------------------------|--|
| Input                    |                  |                            |  |
| Voltage                  | EVAL-IMI111T-026 | 110 – 230 V <sub>AC</sub>  |  |
|                          | EVAL-IMI111T-046 |                            |  |
| Output                   |                  |                            |  |
| Current per phase        | EVAL-IMI111T-026 | 420 mA <sub>rms</sub>      | t <sub>amb</sub> = 20°C, t <sub>case</sub> = 100°C, V <sub>DC</sub> = 311 V, 2-phase modulation, 6 kHz PWM |
|                          | EVAL-IMI111T-046 | 570 mA <sub>rms</sub>      |  |
| DC bus voltage           |                  |                            |  |
| Maximum DC bus voltage   | EVAL-IMI111T-026 | 380 V                      |  |
|                          | EVAL-IMI111T-046 |                            |  |
| Minimum DC bus voltage   | EVAL-IMI111T-026 | 120 V                      |  |
|                          | EVAL-IMI111T-046 |                            |  |
| Current feedback         |                  |                            |  |
| Current sensing resistor | EVAL-IMI111T-026 | 250 mΩ                     | The current sensing configuration is single-shunt  |
|                          | EVAL-IMI111T-046 | 250 mΩ                     |  |
| Onboard power supply     |                  |                            |  |
| 15 V                     | EVAL-IMI111T-026 | 15 V ±5%, max. 50 mA       | Used for iMOTION™ IPMs gate driver   |
|                          | EVAL-IMI111T-046 |                            |  |
| 3.3 V                    | EVAL-IMI111T-026 | 3.3 V ±2%, max. 20 mA      | Supplying 3.3 V to the controller  |
|                          | EVAL-IMI111T-046 |                            |  |
| PCB characteristics      |                  |                            |  |
| Material                 | EVAL-IMI111T-026 | FR4, 2 layers, 2 oz copper |  |
|                          | EVAL-IMI111T-046 |                            |  |
| Dimension                | EVAL-IMI111T-026 | 79.6 mm x 89.6 mm          |  |
|                          | EVAL-IMI111T-046 |                            |  |
| System environment       |                  |                            |  |
| Ambient temperature      | EVAL-IMI111T-026 | From 0 to 60°C             | Non-condensing, maximum RH of 95%  |
|                          | EVAL-IMI111T-046 |                            |  |



### Main features

Figure 2 shows the functional groups on the top side of the EVAL-IMI111T-026 evaluation board. EVAL-IMI111T-046 is similar to EVAL-IMI111T-026, except item 6 is the IMI111T-046H module.

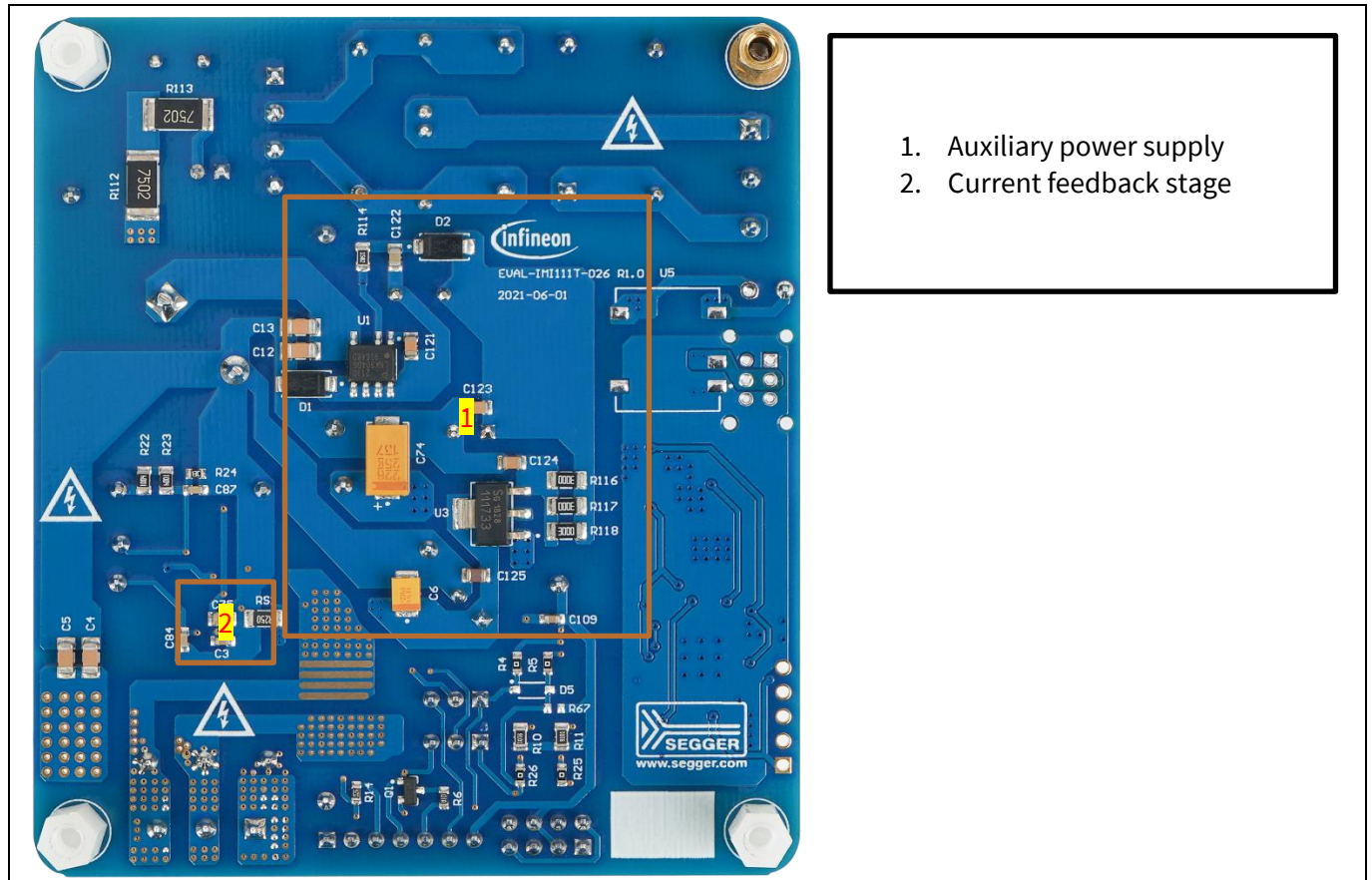


**Figure 2 Functional group on the top side of EVAL-IMI111T**



### Main features

Figure 3 shows the functional groups on the bottom side of the Eval-IMI111T-026 evaluation board. This is same for both EVAL-IMI111T-046 and EVAL-IMI111T-026.



**Figure 3 Functional group on the bottom side of EVAL-IMI111T**

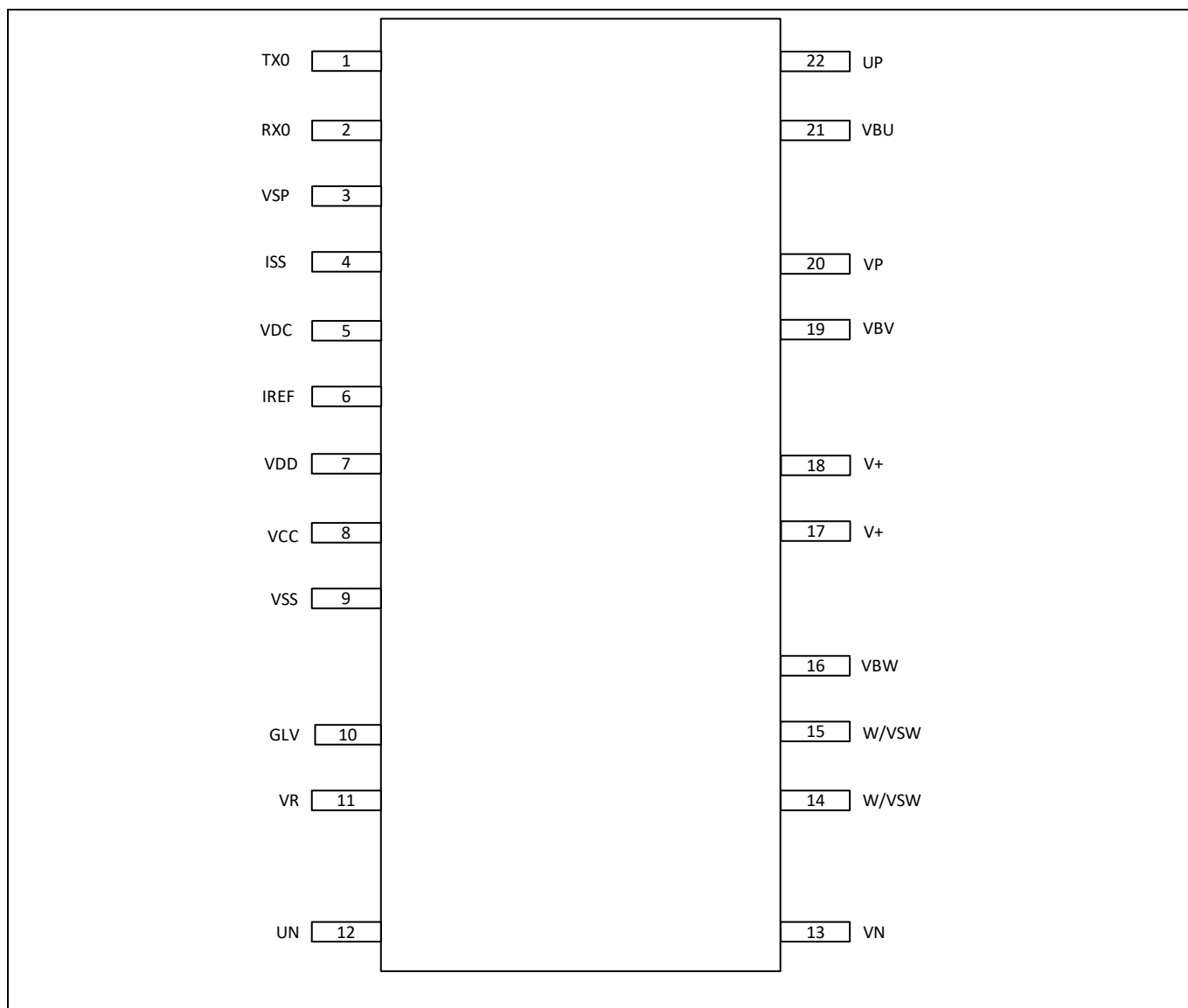
**Pin assignments**

### 3 Pin assignments

**Table 4 Pinout description for IMI111T [1]**

| Pin | Name  | Type | Description  |
|-----|-------|------|--|
| 1   | TX0   | O    | Serial port transmit output  |
| 2   | RX0   | I    | Serial port receive input  |
| 3   | VSP   | AIN  | Analog speed reference input   |
| 4   | ISS   | AIN  | Single-shunt current sense input                                     |
| 5   | VDC   | AIN  | DC bus sensing input   |
| 6   | IREF  | O    | Overcurrent reference DAC output                                     |
| 7   | VDD   | P    | Digital controller supply  |
| 8   | VCC   | P    | Low side gate driver supply  |
| 9   | VSS   | P    | Control signal ground  |
| 10  | GLV   | NC   | Gate of low side IGBT of phase V (do not connect on PCB)             |
| 11  | VR    | P    | 3-phase low side IGBT common emitter return                          |
| 12  | UN    | P    | U phase low side IGBT collector (needs PCB connection to UP)         |
| 13  | VN    | P    | V phase low side IGBT collector (needs PCB connection to VP)         |
| 14  | W/VSW | P    | W phase output (bootstrap capacitor connection -)                    |
| 15  | W/VSW | P    | W phase output (bootstrap capacitor connection -)                    |
| 16  | VBW   | P    | W phase high side floating supply (bootstrap capacitor connection +) |
| 17  | V+    | P    | DC bus voltage positive  |
| 18  | V+    | P    | DC bus voltage positive  |
| 19  | VBV   | P    | V phase high side floating supply (bootstrap capacitor connection +) |
| 20  | VP    | P    | V phase high side IGBT emitter (needs PCB connection to VN)          |
| 21  | VBU   | P    | U phase high side floating supply (bootstrap capacitor connection +) |
| 22  | UP    | P    | U phase high side IGBT emitter (needs PCB connection to UN)          |

## Pin assignments



**Figure 4 IMI111T pinout** Error! Reference source not found.

General information about the connectors of the EVAL-IMI111T evaluation board is provided in the following tables:

**Table 5 J1 connector description**

| Pin | Name    | Details                       |
|-----|---------|-------------------------------|
| 1   | EARTH   | Earth ground                  |
| 2   | LINE    | AC-line input (110 V – 240 V) |
| 3   | NEUTRAL | AC neutral input              |

**Table 6 J2 jumper description**

| Pin | Name   | Details   |
|-----|--------|---|
| 1   | RXD0   | RXD0 for UART communication   |
| 2   | RX/DIR | RX for UART and DIR for direction (default jumper position to RXD0) |
| 3   | DIR    | Direction pin   |

**Pin assignments**

**Table 7 J3 connector description**

| Pin | Name | Details                    |
|-----|------|----------------------------|
| 1   | U    | Connected to motor phase U |
| 2   | V    | Connected to motor phase V |
| 3   | W    | Connected to motor phase W |

**Table 8 J4 jumper description**

| Pin | Name     | Details   |
|-----|----------|---|
| 1   | TXD0     | TXD0 for UART communication   |
| 2   | TX/PGOUT | TX for UART and PGOUT for pulses per revolution (default jumper position to TXD0) |
| 3   | PGOUT    | Pulses per revolution   |

**Table 9 J5 connector description**

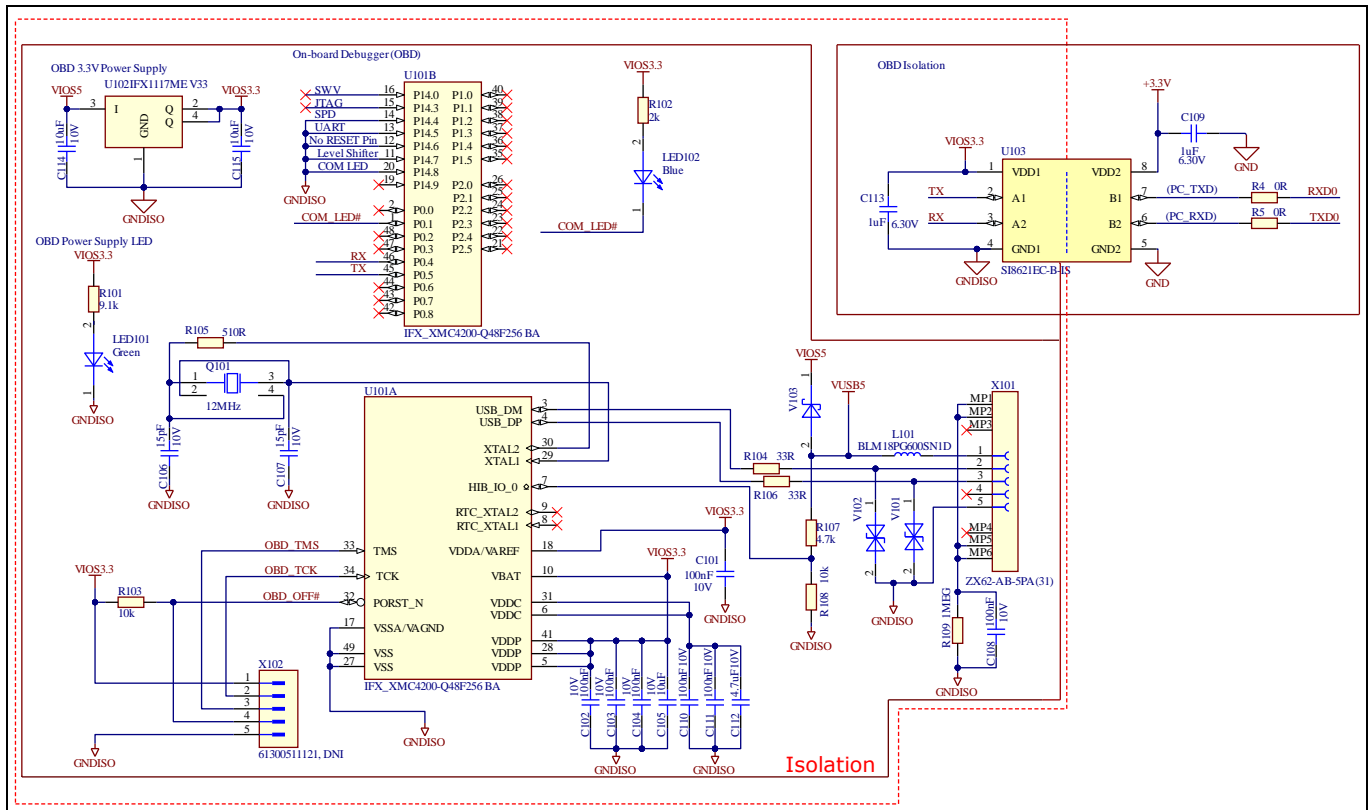
| Pin | Name   | Details  |
|-----|--------|--|
| 1   | GND    | Ground   |
| 2   | VSP_IN | Input for analog Vsp control filtered                  |
| 3   | VSP    | Input for analog Vsp control                           |
| 4   | PGOUT  | Pulses per revolution                                  |
| 5   | FG     | Pulses per revolution, open drain output 15 V tolerant |
| 6   | DIR    | Direction pin  |
| 7   | 3.3 V  | Onboard 3.3 V supply                                   |

**Table 10 J7 connector description**

| Pin | Name  | Details                     |
|-----|-------|-----------------------------|
| 1   | TXD0  | TXD0 for UART communication |
| 2   | RXD0  | RXD0 for UART communication |
| 3   | 3.3 V | Onboard 3.3 V supply        |
| 4   | GND   | Ground                      |
| 5   | GND   | Ground                      |
| 6   | 3.3 V | Onboard 3.3 V supply        |
| 7   | RXD0  | RXD0 for UART communication |
| 8   | TXD0  | TXD0 for UART communication |

## 4 System performance

To meet individual customer requirements and to help them make the EVAL-IMI111T evaluation board a basis for development or modification of their own boards, all necessary technical data such as schematics, layout, and components are included in this chapter. Figure 5, Table 6Figure 6, and Figure 7 provide an overview of the different parts of EVAL-IMI111T. The details are analyzed in subsequent chapters.



**Figure 5 Overview of the isolated debug part**

# EVAL-IMI111T user guide

## iMOTION™ MADK starter kit for IMI111T IPMs

### System performance

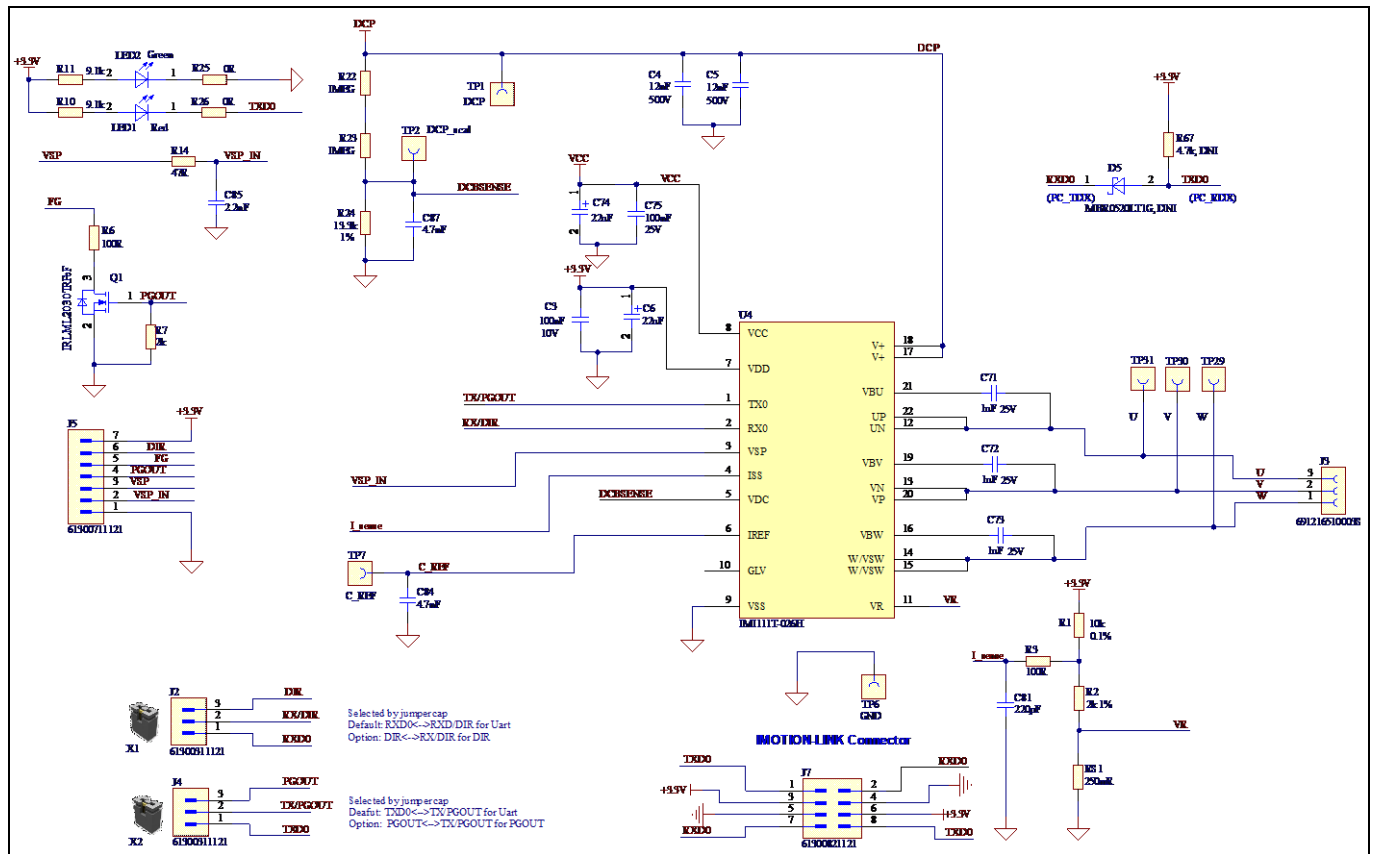


Figure 6 Overview of power and control

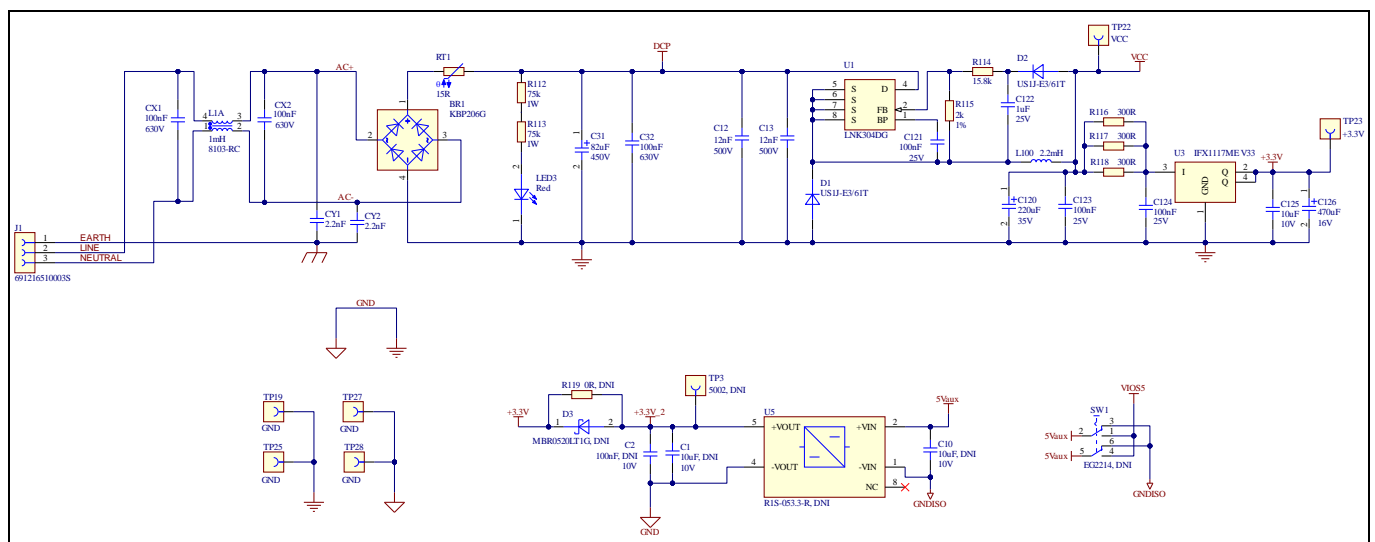


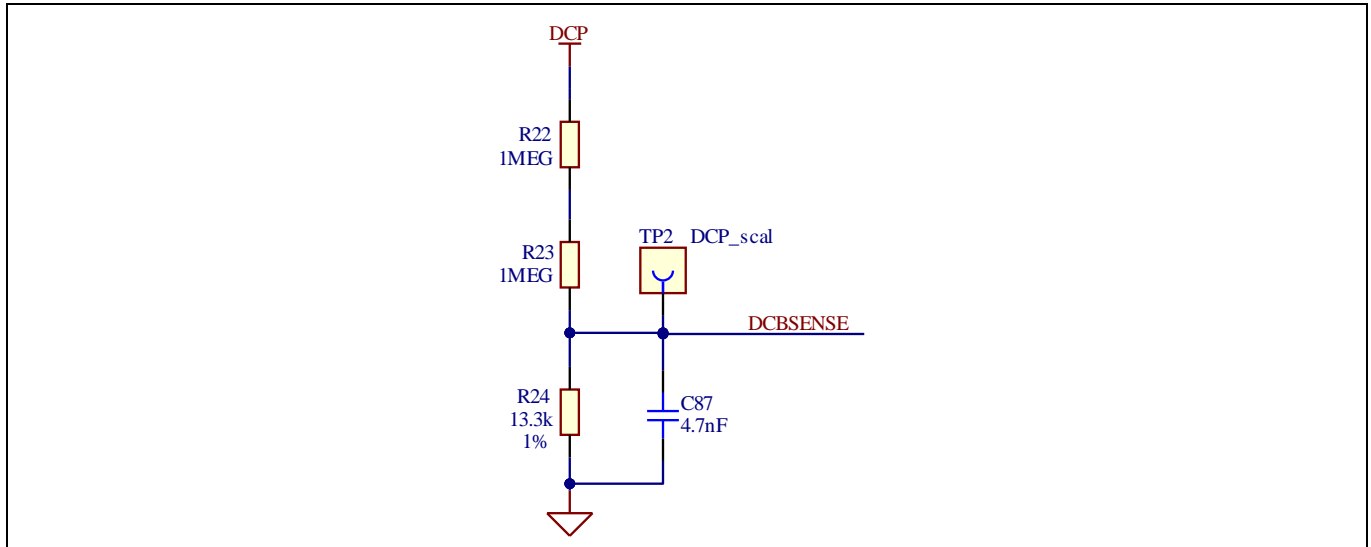
Figure 7 Overview of power supplies

## 4.1 DC-link voltage measurement

Figure 8 shows the details of the DC bus sense resistor.



## System performance

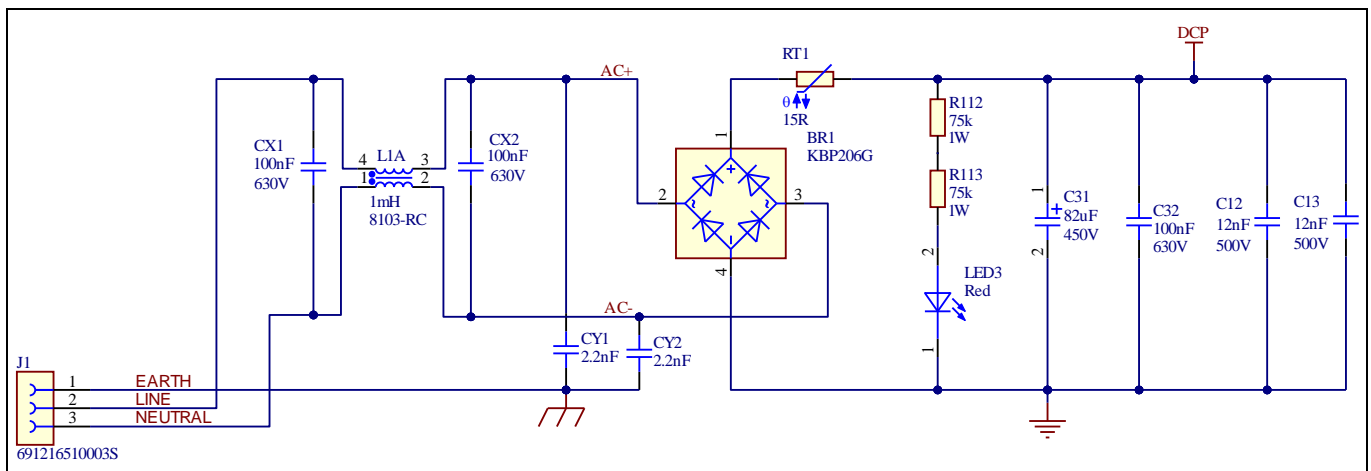


**Figure 8 DC bus sense resistor on the EVAL-IMI111T evaluation board**

The DCBSENSE voltage is read by the VDC pin of the controller. With 13.3 kΩ as pull-down resistor, the DCBSENSE voltage causes a range of 0 to 3.3 V on the pin reflecting a DC bus voltage range of 0 to 500 V.

## 4.2 EMI filter

Figure 9 shows the schematic from the AC-line input connector J1 to the rectified DC bus voltage. This circuitry includes a passive EMI filter consisting of the elements CX1, CX2, L1, CY1, and CY2, a 2 A/600 V rectifier (BR1), an NTC resistor RT1, two ceramic capacitors C12 and C13, a film capacitor C32, and an electrolytic capacitor C31 for buffering the rectified DC bus voltage DCP.



**Figure 9 Schematic of EMI filter and AC/DC section of the EVAL-IMM101T evaluation board**

## 4.3 Inverter section using iMOTION™ IPM

The inverter section is implemented as shown in Figure 10. The 3-phase inverter consist of six IGBTs with the following blocking voltages and current capability depending on the part number:

- IMI111T - 026H - DC rating: 600 V/2 A
- IMI111T - 046H - DC rating: 600 V/4 A

## EVAL-IMI111T user guide

### iMOTION™ MADK starter kit for IMI111T IPMs

#### System performance

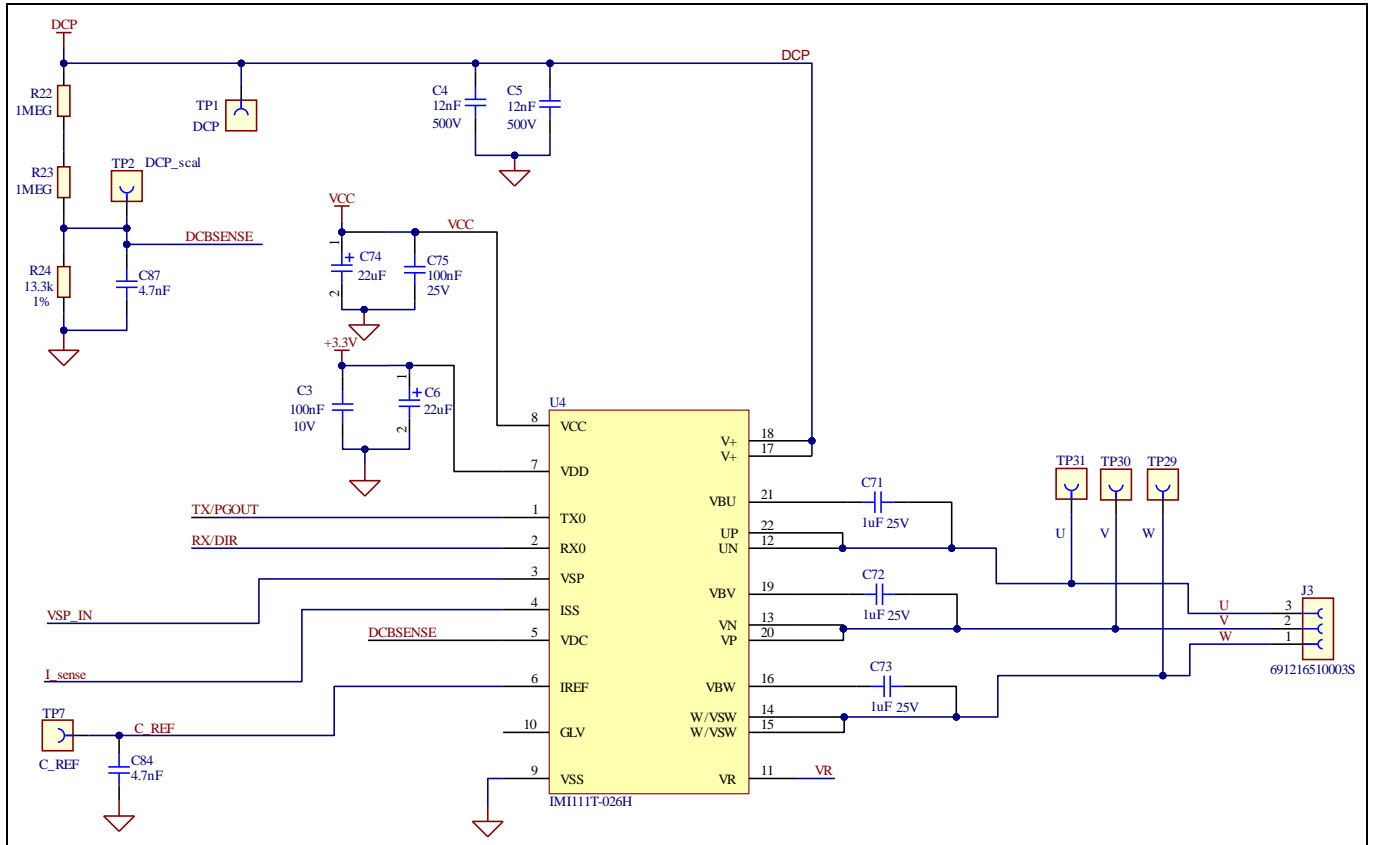


Figure 10 Schematic of the 3-phase inverter section using iMOTION™ IPM IMI111T on EVAL-IMI111T

#### 4.4 Auxiliary power supply

Figure 11 shows the schematic of the auxiliary power supply available on the EVAL-IMI111T board. The circuit includes a LNK304 that is used to generate 15 V directly from the DC bus.  $V_{cc}$  is connected to the gate driver inside the iMOTION™ IPM using pin 8 of the module. The linear voltage regulator IFX1117MEV33 generates 3.3 V from a 15 V power supply  $V_{CC}$ . The 3.3 V supplies the control IC inside the iMOTION™ IPM.

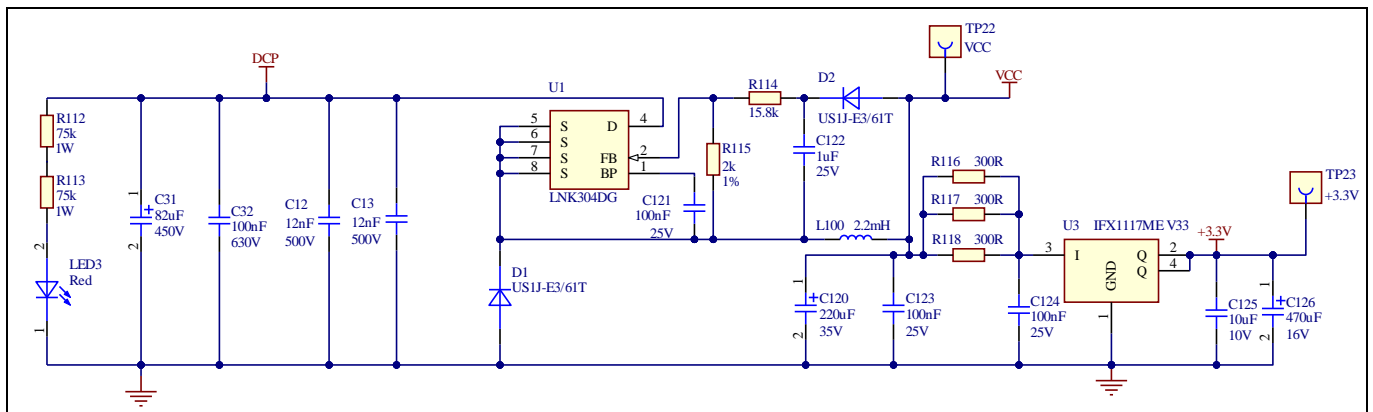
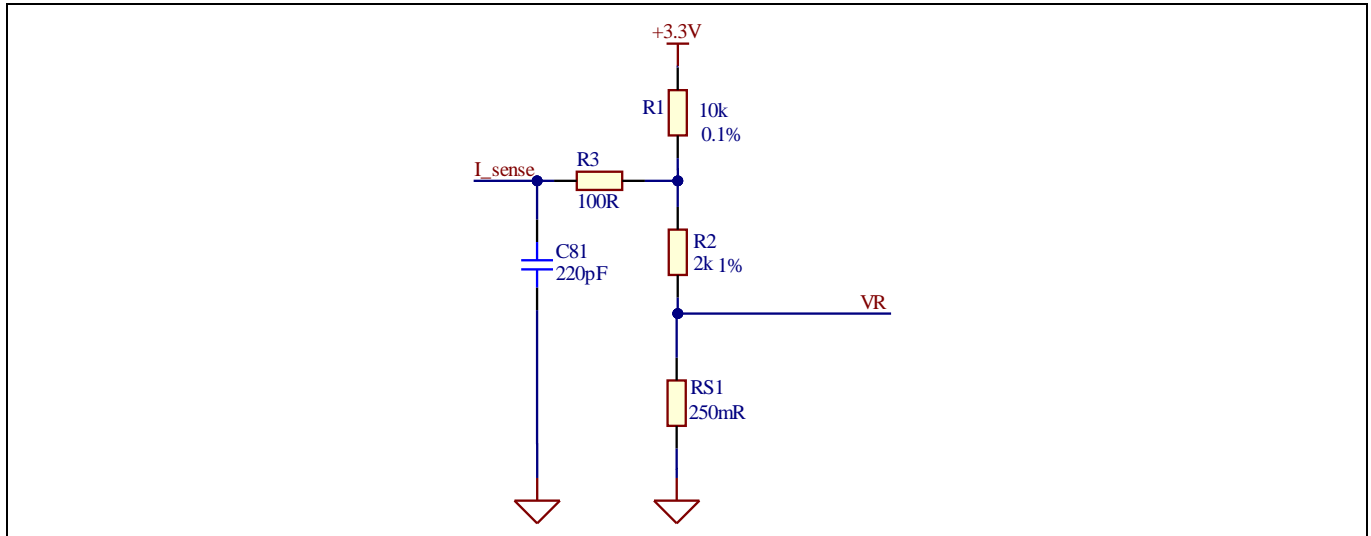


Figure 11 Power supply section of the EVAL-IMI111T evaluation board

#### 4.5 Current measurement shift stage and overcurrent threshold

Figure 12 shows the details of the current measurement shift stage.

## System performance



**Figure 12** Current measurement shift stage

In a single-shunt configuration, resistor RS1 is purposed to generate a voltage proportional to the sum of the source currents of the low side power IGBTs. This voltage is shifted using the shift stage shown in Figure 12 and is measured at pin ISS.

The shift stage is made of a voltage divider and a low pass filter. Using the superposition theorem, it is possible to calculate the input current scaling and the shift stage offset. The input current scaling can be calculated using the following formula:

$$\text{Input Current Scaling} = RS_1 \frac{R_1}{R_1 + R_2} V/A$$

The ADC dynamic range can be calculated using the following formula:

$$\text{ADC range} = \frac{\text{Input Current Scaling}}{3.3 V} \times \text{Internal Gain} \times (2^{12} - 1) \text{ counts/A}$$

Internal gain can be set via the iMOTION™ Solution Designer and the default value for EVAL-IMI111T is equal to 3. Particular attention has to be paid when setting the internal gain to avoid saturating the ADC; it can cause a continuous GateKill fault status.

The shift stage offset can be calculated using the following formula:

$$\text{Shift Stage Offset} = \frac{R_2}{R_1 + R_2} \times 3.3 V$$

The overcurrent comparator reference voltage can be calculate using the following formula:

$$\text{OVC Threshold} = (I_{MAX peak} \times \text{Input Current Scaling} + \text{Shift Stage Offset}) V$$

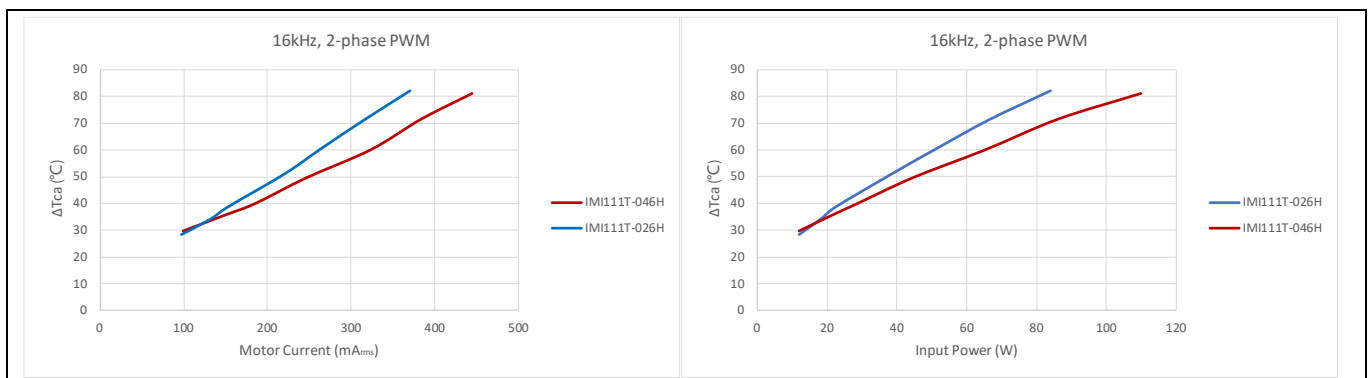
## Thermal characterization

### 5 Thermal characterization

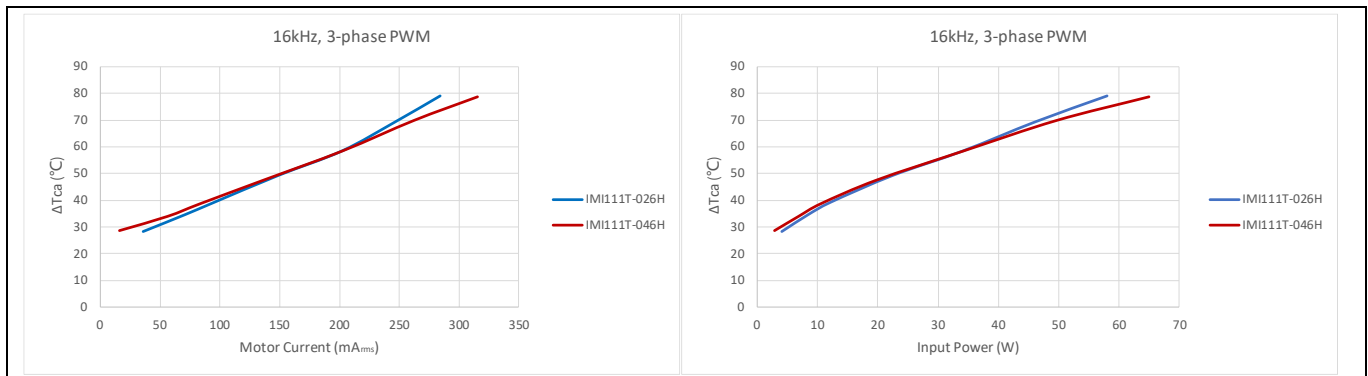
Figure 13, Figure 14, Figure 15, Figure 16, Figure 17, and Figure 18 show the thermal characterizations of the two part numbers. The tests were performed under the following conditions:

$T_{amb} = 20^{\circ}\text{C}$ , input voltage = 220 Vrms ( $V_{DC} = 311\text{ V}$ ), two different PWM modulation types (3-phase PWM modulation and 2-phase PWM flat bottom modulation).

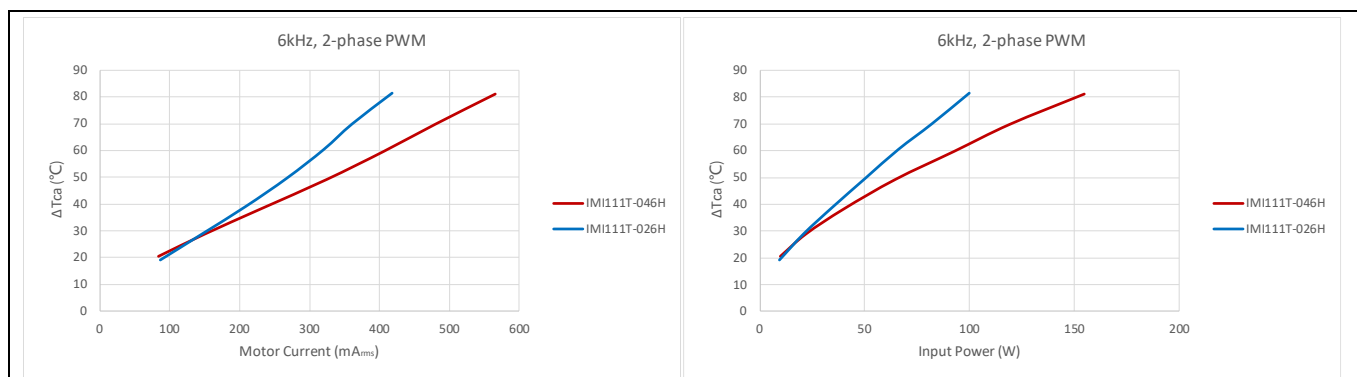
Figure 13, Figure 14, Figure 15, and Figure 16 show results of tests performed under two PWM frequencies (6 kHz and 16 kHz) and different motor phase current values or different input powers. Figure 17 and Figure 18 show results of tests performed under different PWM frequencies (4 kHz to 20 kHz) till  $T_{case} = 100^{\circ}\text{C}$  was reached. A 2-phase PWM flat bottom modulation enabled the reduction in switching losses compared to a 3-phase SVPWM (symmetrical placement of zero vectors).



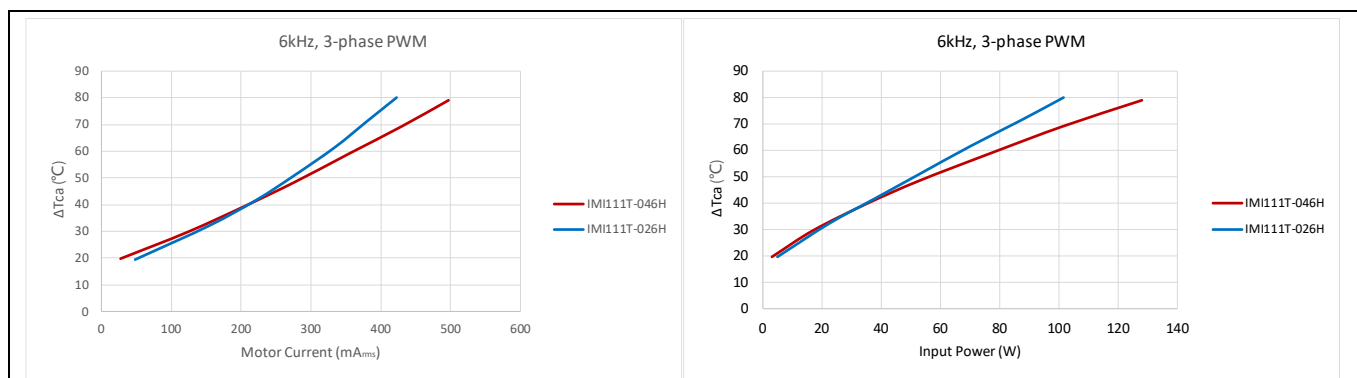
**Figure 13 Thermal characterization of IMI111T-026H vs IMI111T-046H, 2-phase PWM, 16 kHz, FR4 PCB with 2 oz copper**



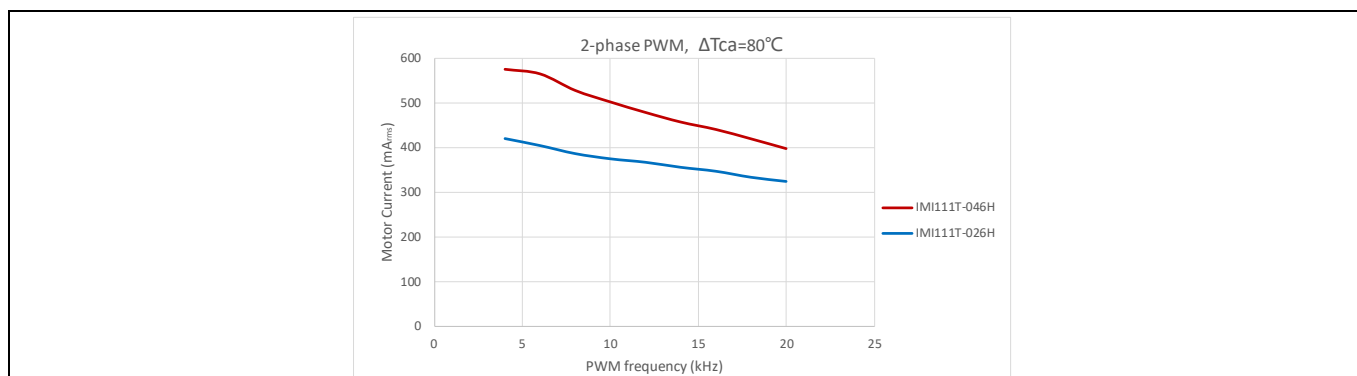
**Figure 14 Thermal Characterization of IMI111T-026H vs IMI111T-046H, 3-phase PWM, 16 kHz, FR4 PCB with 2 oz copper**



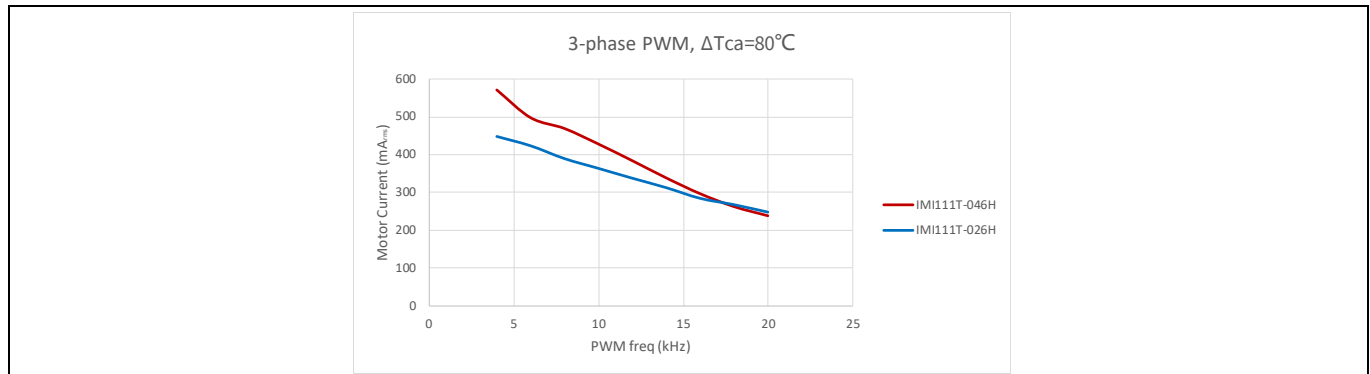
**Figure 15 Thermal Characterization of IMI111T-026H vs IMI111T-046H, 2-phase PWM, 6 kHz, FR4 PCB with 2 oz copper**



**Figure 16 Thermal Characterization of IMI111T-026H vs IMI111T-046H, 3-phase PWM, 6 kHz, FR4 PCB with 2 oz copper**



**Figure 17 Thermal Characterization of IMI111T-026H vs IMI111T-046H, 2-phase PWM,  $\Delta T_{ca} = 80^{\circ}\text{C}$ , FR4 PCB with 2 oz copper**



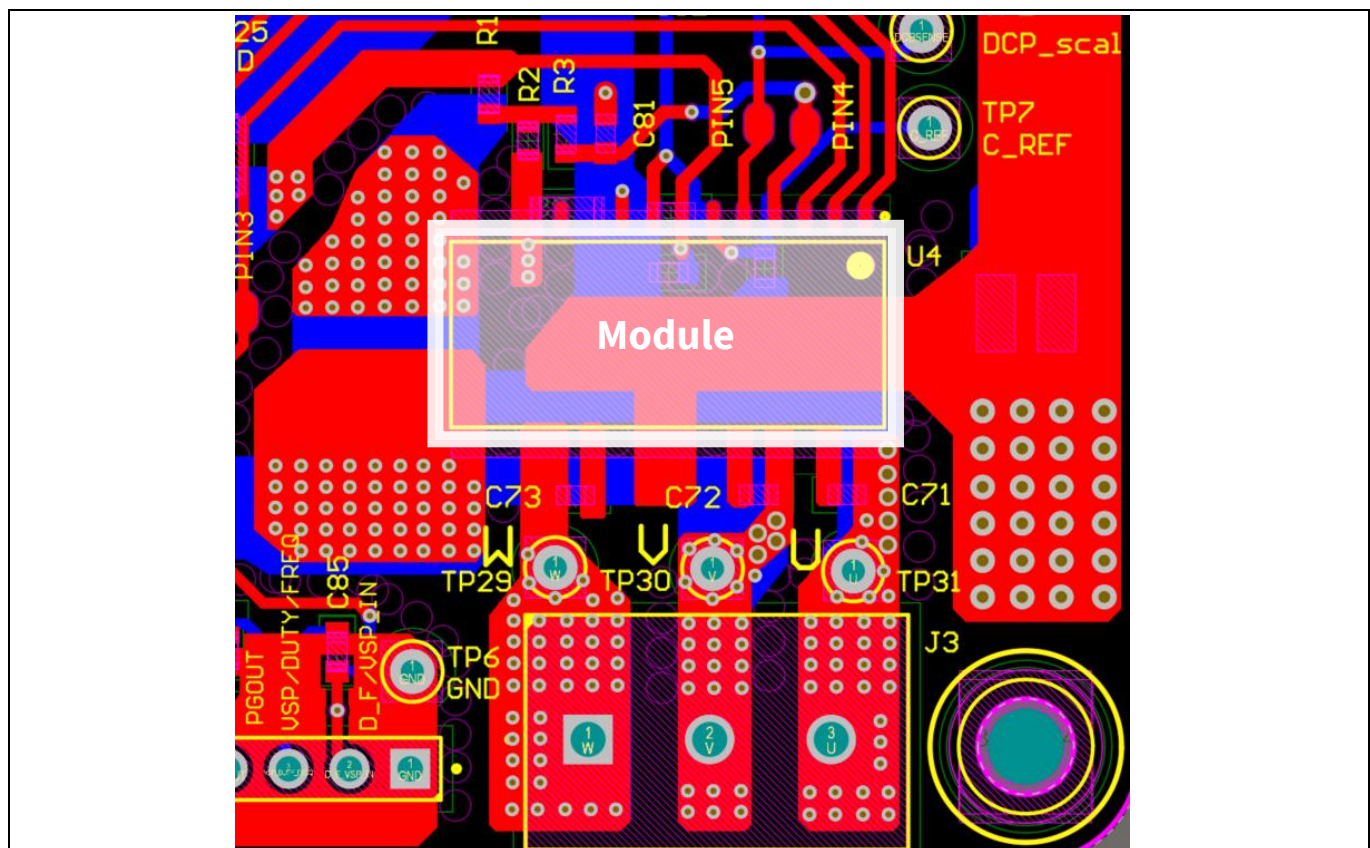
**Figure 18 Thermal Characterization of IMI111T-026H vs IMI111T-046H, 3-phase PWM,  $\Delta T_{ca} = 80^{\circ}\text{C}$ , FR4 PCB with 2 oz copper**

## 5.1 Thermal characteristic

**Table 11 Thermal Characteristics**

| Symbol                       | Description                           | Min | Typ | Max | Units                       |
|------------------------------|---------------------------------------|-----|-----|-----|-----------------------------|
| $R_{th(C-A)}_{IMI111T-026H}$ | Thermal resistance<br>Case to ambient | --- | 31  | --- | $^{\circ}\text{C}/\text{W}$ |
| $R_{th(C-A)}_{IMI111T-046H}$ |                                       |     | 30  |     |                             |

The value of  $R_{th(C-A)}$  was obtained using a dissipated power of 2 W in the module and a FR4 PCB with 2 oz copper. The PCB layout is shown in Figure 19.



**Figure 19 PCB layout used for thermal characterization: 2 oz copper, 2 layers**



## 5.2 Thermal PCB design

IMI111T relies on the leads to transfer thermal dissipation from the power devices to the PCB. There are several critical pins that need attention to achieve improved thermal performance of the module. Figure 20 shows the pins critical for thermal dissipation. These include V+ (17, 18), UN (12), VN (13), and W (14, 15). Copper areas connected to the critical pins have to be optimized as much as possible on both layers to provide more thermal transfer capability. Figure 21 shows the PCB design on both layers with respect to the critical pins.

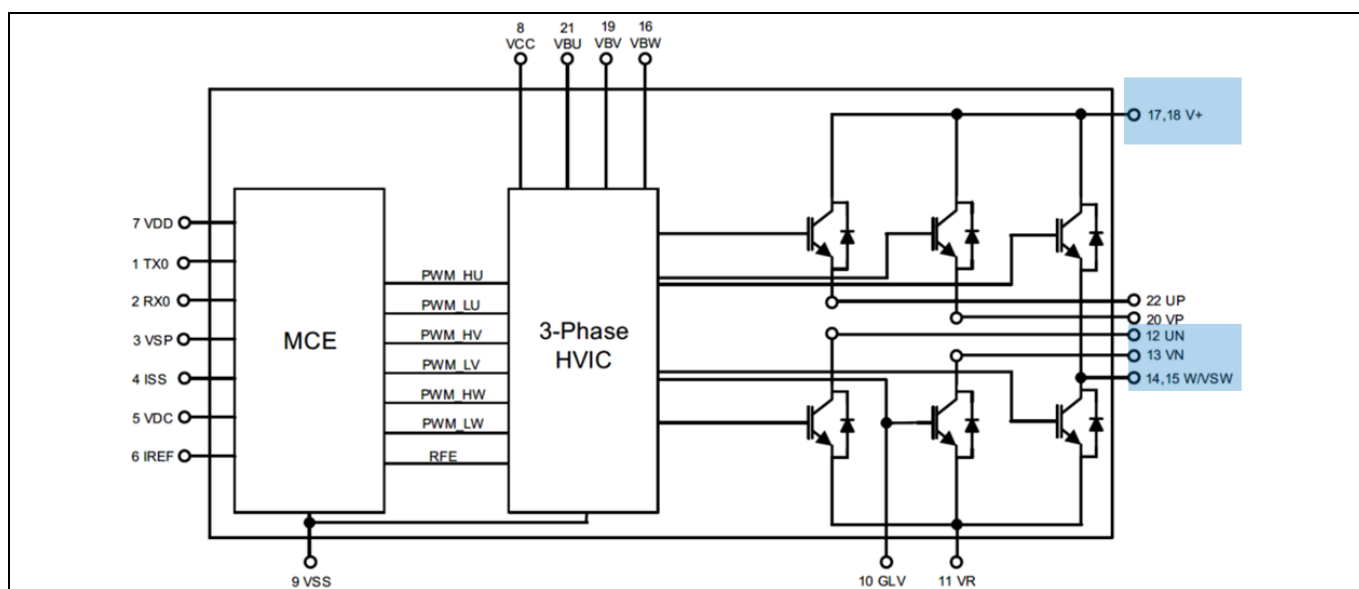


Figure 20 Critical pins for thermal PCB design

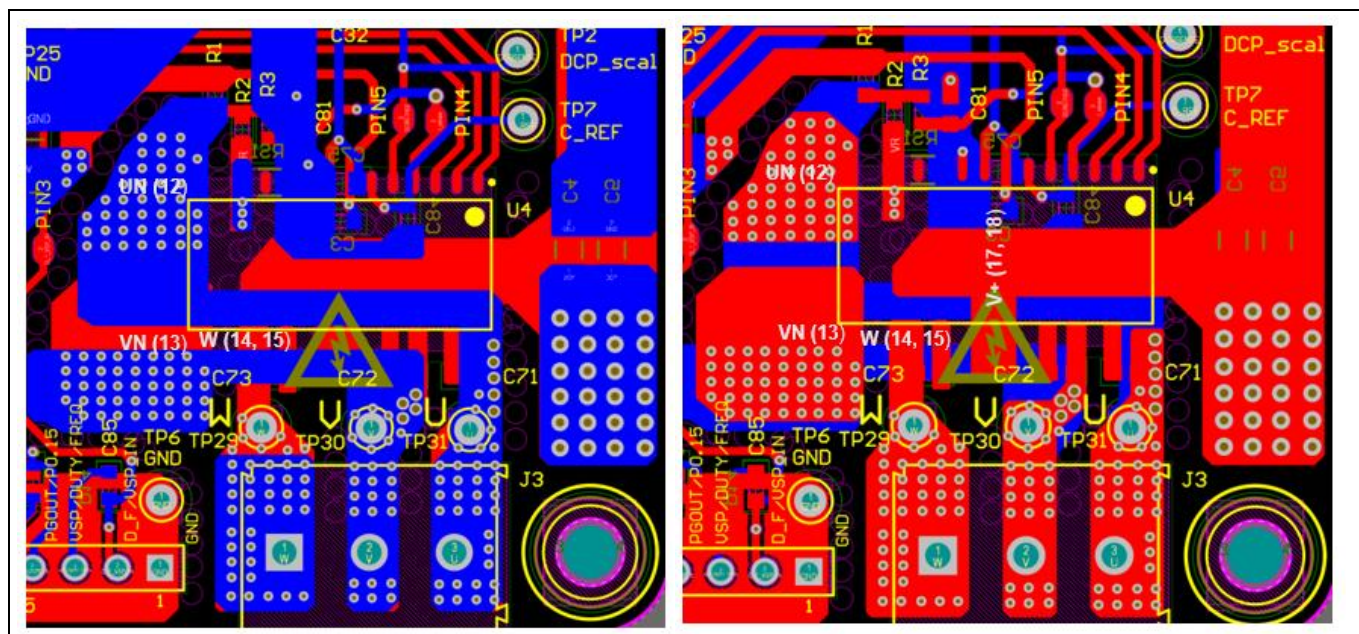


Figure 21 Eval board PCB designs for both the top and bottom layers regarding critical pins

## 6 Thermal protection

The IMI111T devices feature an integrated temperature sensor that helps in monitoring the internal temperature of the module. The device temperature can be accessed using script engine language. The particular register name for this functionality is “InternalDieTemp [2]” in iMOTION™ Solution Designer dashboard variables list and the register value is in Kelvin [K].

To enable overtemperature protection for the EVAL-IMI111T starter kit, a corresponding script file (.mgs) has been pre-loaded into the IMI111T mounted on the EVAL-IMI111T starter kit, along with the latest IMI111T software package and parameters.

To activate the overtemperature protection, the script project needs to be set up, built, and programmed in iMOTION™ Solution Designer script editor window during system setup. Please refer to the application note How to use iMOTION™ Script Language [2][3] for more details about the iMOTION™ script functionality. Chapter 7 of this user guide provides the operative method for script application.

The script that is used for overtemperature protection in EVAL-IMI111T is shown in Code Listing 1, Code Listing 2 and Code Listing 3. The script has been implemented to stop the motor when the sensed temperature reaches 91°C (shutdown temperature) and to restart the motor when the sensed temperature goes below 60°C (restart temperature). Please note that the sensed temperature is the controller temperature, whereas, overtemperature is generally triggered by the case temperature of the module. Based on experimental results, Figure 22 shows the relationship between the case temperature and the internal sense temperature. Customers can use this curve to determine their internal sense temperature for thermal shutdown.

### Code Listing 1 Globales.mcs

```
001:  /*****
      *****/
002:  /*Global variables*/
003:  /*****
      *****/
004:  int Inter_temperature;
```

### Code Listing 2 Script\_Task0.mcs

```
001:  /*Task0 init function*/
002:  Script_Task0_init()
003:  {
004:  /*Local variables declaration*/
005:  int t_hyst, t_shutdown, flag;
006:
007:  /*Global variable initialization*/
008:  Inter_temperature = 0;
009:
010:  /*Local variables initialization*/
011:  t_hyst = 333;
012:  /*60 centigrade, please insert the value in Kelvin*/
013:
014:  t_shutdown = 364;
015:  /*The IC control part internal shutdown die temperature is 91 centigrade when IMI package
      temperature is 100 centigrade. Please insert the value in Kelvin */
016:
017:  flag = 0;
```

## Thermal protection

```

018:
019: }
020: /*****
021:  *****/
022: /*Task0 init function*/
023: Script_Task0()
024: {
025:     Inter_temperature=MCEOS.InternalDieTemp;
026:     if((Inter_temperature < t_hyst)&&(flag == 1))
027:         /*If t_hyst < temperature < t_shutdown, motor is still in stop condition and it is not able to
028:         restart */
029:     {
030:         flag = 0;
031:         APP_MOTOR0.Command = 1;
032:     }
033:     if(Inter_temperature > t_shutdown)
034:         /*If temperature > t_shutdown, motor is stopped*/
035:     {
036:         APP_MOTOR0.Command = 0;
037:         flag = 1;
038:     }
039:     if(flag == 1)
040:     {
041:         APP_MOTOR0.Command = 0;
042:     }
043: }

```

**Code Listing 3**    **Script\_Task1.mcs**

```

001: /*Task1 init function*/
002: Script_Task1_init()
003: {
004:
005: }
006: /*****
007:  *****/
008: /*Task1 init function*/
009: Script_Task1()
010: {
011: }

```

Thermal protection

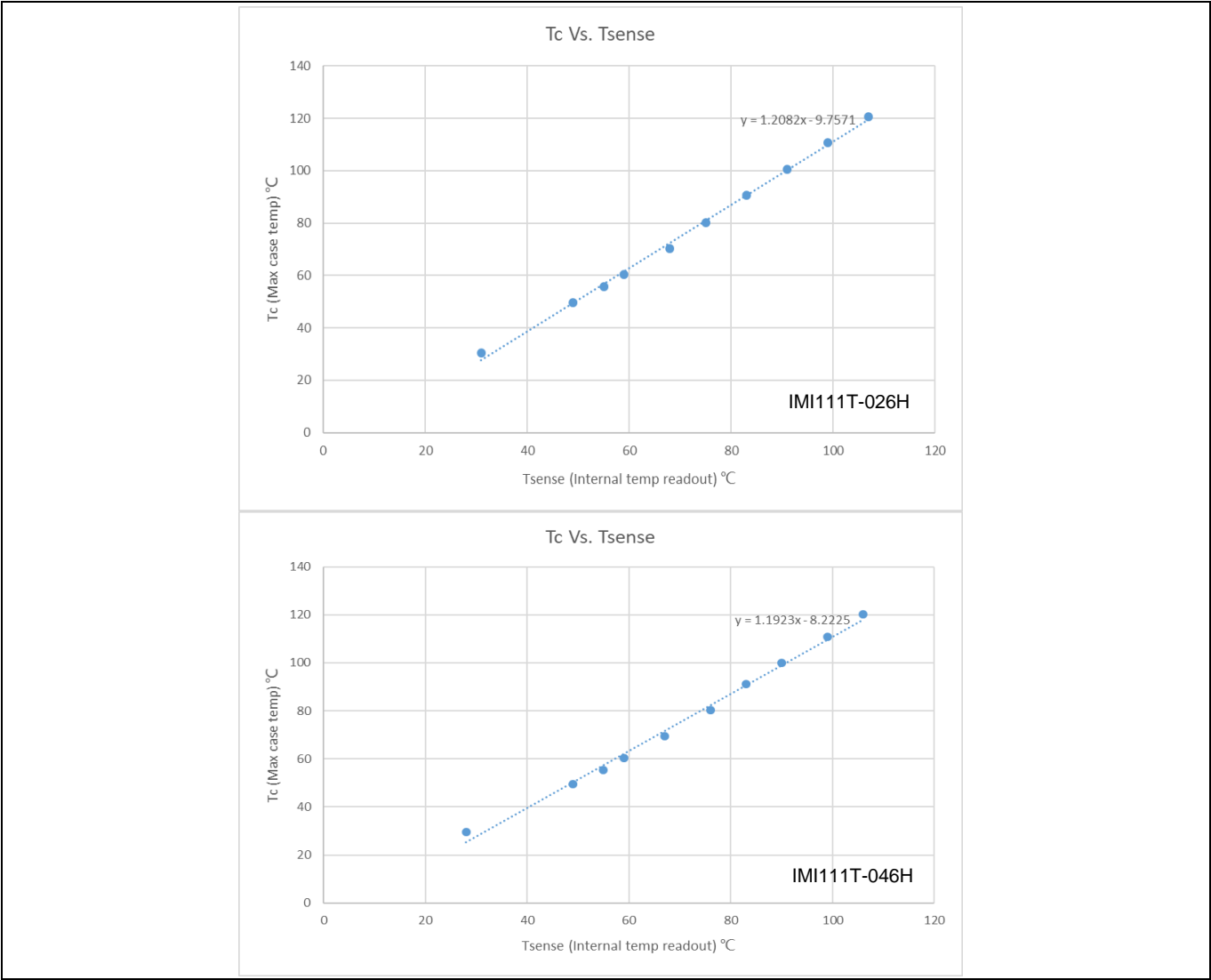


Figure 22 Correlation between the case temperature and the internal temperature readout

## 7 Getting started with EVAL-IMI111T

This chapter provides details on setting up the system and getting started with the iMOTION™ development platform.

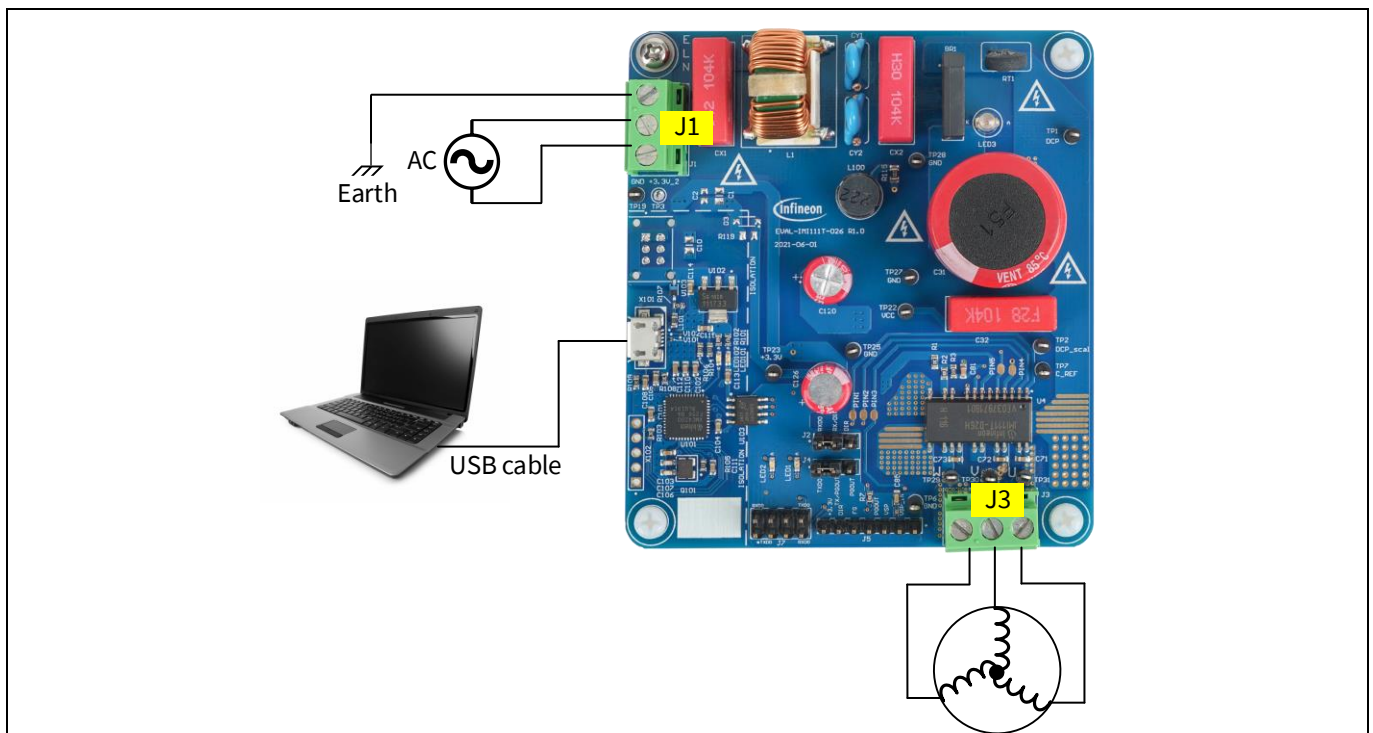
The iMOTION™ development tool, iMOTION™ Solution Designer is required to set up the system, and to control and fine-tune the system performance to match a user's actual needs. This tool is available for download from Infineon's website (<http://www.infineon.com/imotion-software>).

Isolated onboard debugger provides the USB-to-UART bridge between the PC and the target iMOTION™ device with 1 kV DC galvanic isolation between the motor drive system (hot side) and the PC/debugger (cold side). This onboard debugger uses the SEGGER J-Link driver for UART communication with the IMI111T device. The J-Link driver is installed during the installation of the iMOTION™ Solution Designer. In case the driver is not installed properly, please visit the [SEGGER J-Link website](#) to download and install the latest J-Link Software and Documentation pack for Windows.

This board also provides the external debugger interface for iMOTION™ Link. Users can also use iMOTION™ Link to debug this board instead of the onboard debugger. iMOTION™ Link is also isolated. For more information about iMOTION™ Link, please visit the [iMOTION™ Link](#) page on Infineon's website.

### 7.1 Hardware connection

There are two methods to debug the board. One is to use the onboard debugger and another is to use the external debugger, iMOTION™ Link. Before debugging, the board needs to be connected PC using either of these two methods.



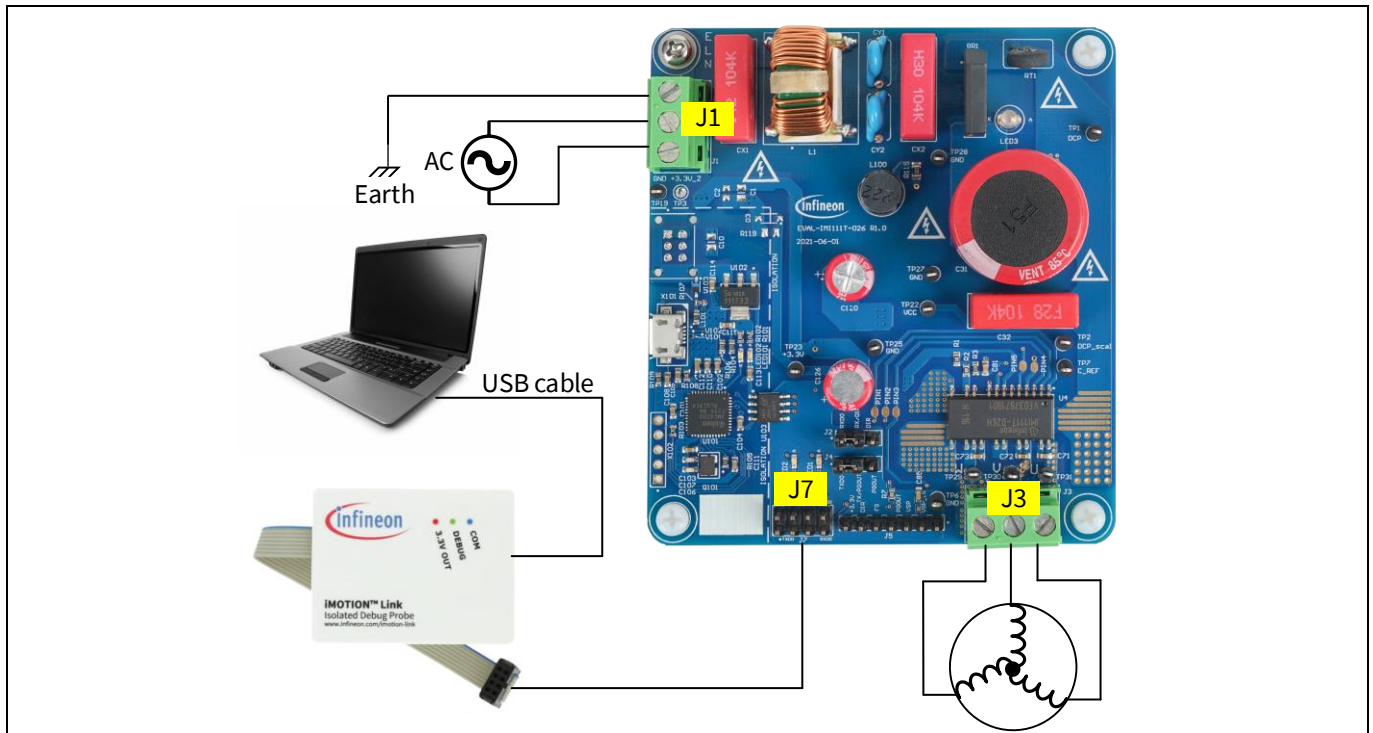
**Figure 23 Method 1: Using onboard debugger**

#### Method 1: Using the onboard debugger

Follow these steps:

#### Getting started with EVAL-IMI111T

1. Ensure the jumper on J2 is connected to “RXD0” and “RX/DIR” and the jumper on J4 is connected to “TXD0” and “TX/PGOUT”.
2. Connect the PC-USB connector to the onboard debugger via the USB cable.
3. Connect AC power and earth to J1.
4. Connect motor to J3. Please note the sequence of U, V, and W phases and change the sequence of any two phases if the motor’s running direction needs to be altered.



**Figure 24 Method 2: Using an external debugger**

#### Method 2: Using an external debugger

Follow these steps:

1. Ensure the jumper on J2 is connected to “RXD0” and “RX/DIR” and the jumper on J4 is connected to “TXD0” and “TX/PGOUT”.
2. Remove the resistors R4 and R5 from the back of the board (R4 and R5 must be soldered for using the onboard debugger).
3. Connect PC-USB connector to iMOTION™ Link via the USB cable.
4. Connect iMOTION™ Link to J7. Any plugging direction is okay for this board.
5. Connect AC power and earth to J1.
6. Connect motor to J3. Please note the sequence of U, V, and W phases sequence and change the sequence of any two phases if the motor’s running direction needs to be altered.

## 7.2 Getting started with iMOTION™

Please refer to the document iMOTION™ Solution Designer [4] for information on how to use the iMOTION™ Solution Designer tuning tool.



### 7.3 UART function switching

To use Pin1 and Pin2 as UART, users must ensure that the RXD0” and “RX/DIR” of jumper J2 are connected and “TXD0” and “TX/PGOUT” of jumper J4 are connected.

To use Pin1 as PG\_OUT and Pin2 as DIR, users must ensure that “PGOUT” and “TX/PGOUT” of jumper J4 are connected and “DIR” and “RX/DIR” of jumper J2 are connected. In this case, connection to iSD is no longer available.

Please refer to the document How to Use UART Interface of IMM101T and IMI111T [5] for information on how to configure this function.

## PCB layout

### 8 PCB layout

The layout of this board can be used for different voltage or power classes. The power PCB is a 2-layer PCB. Get in touch with Infineon's technical support team to get detailed information and the latest gerber files.

Figure 26 shows the top assembly print of the evaluation board.

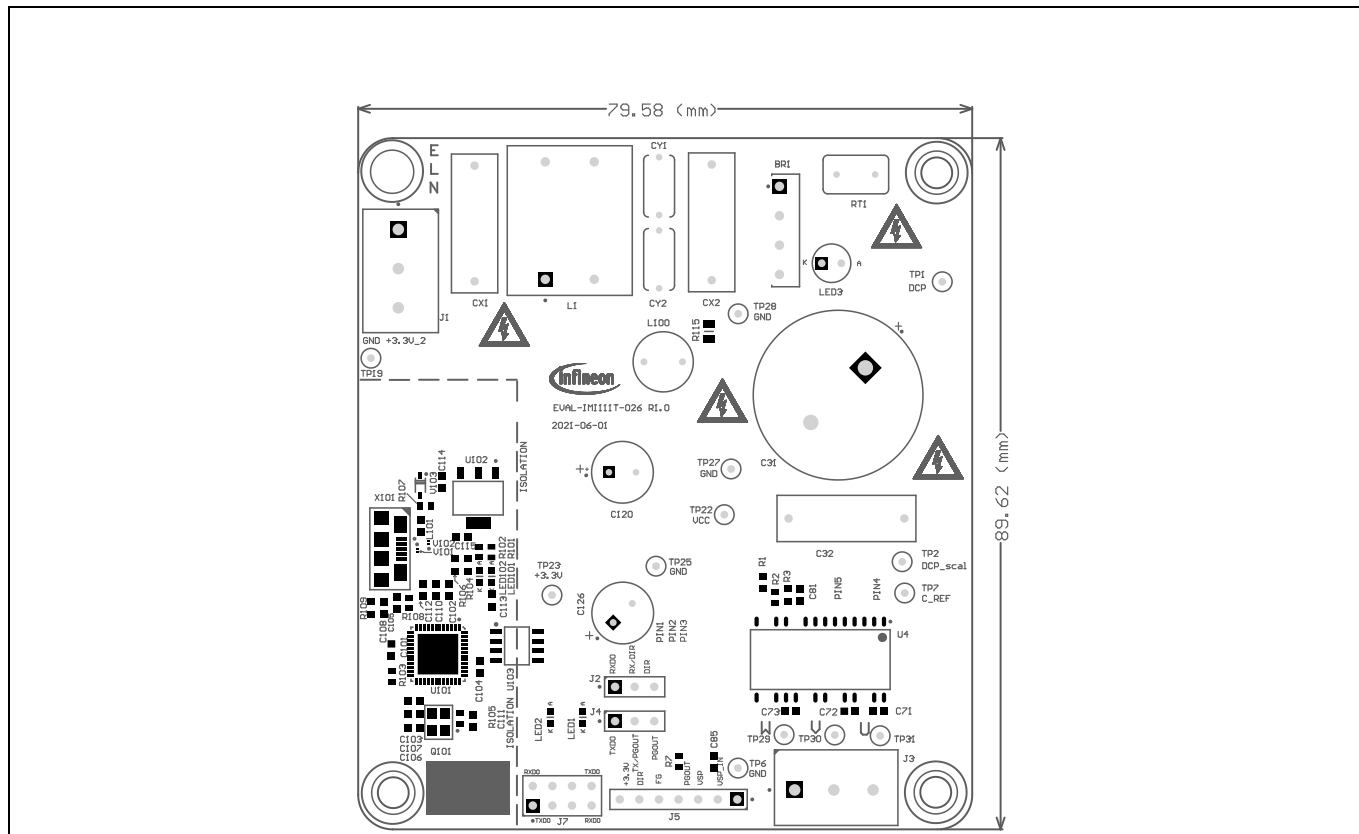
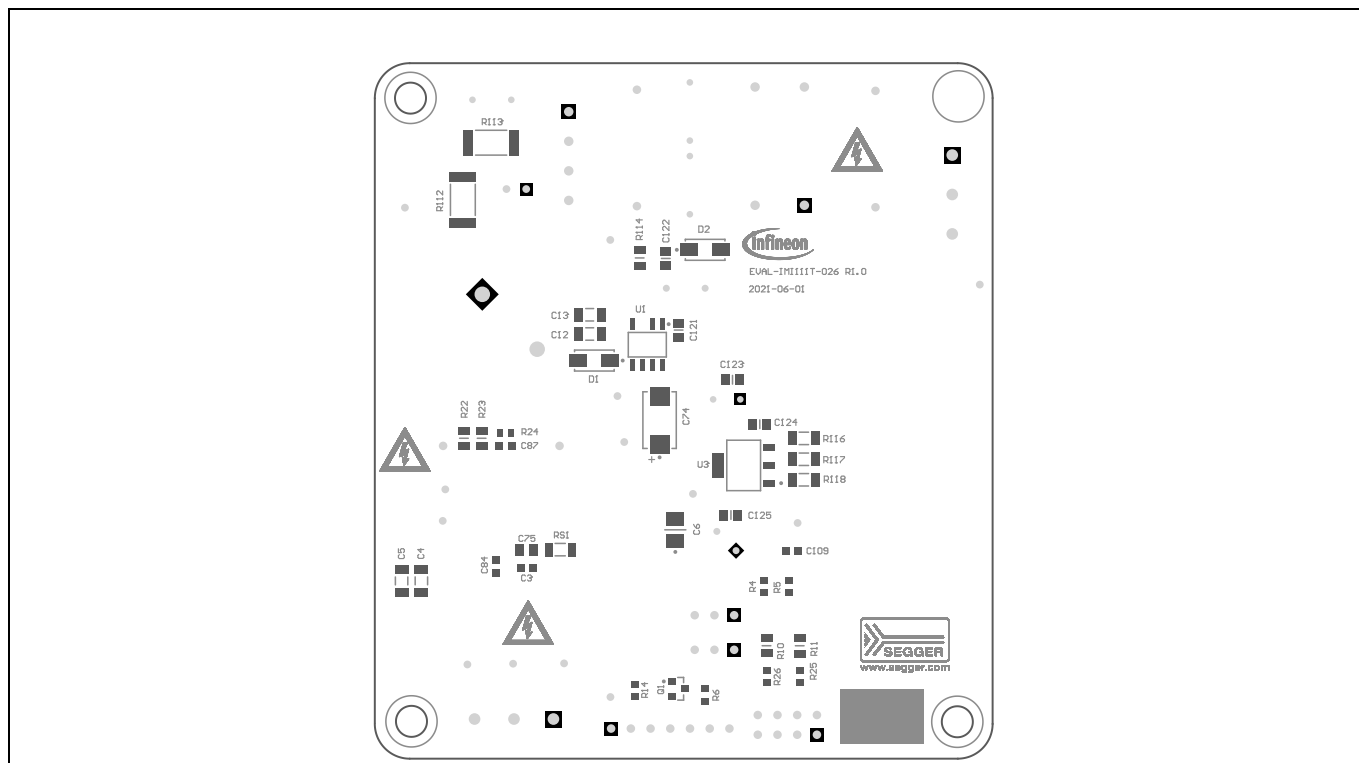


Figure 26 Top assembly print of the EVAL-IMI111T evaluation board

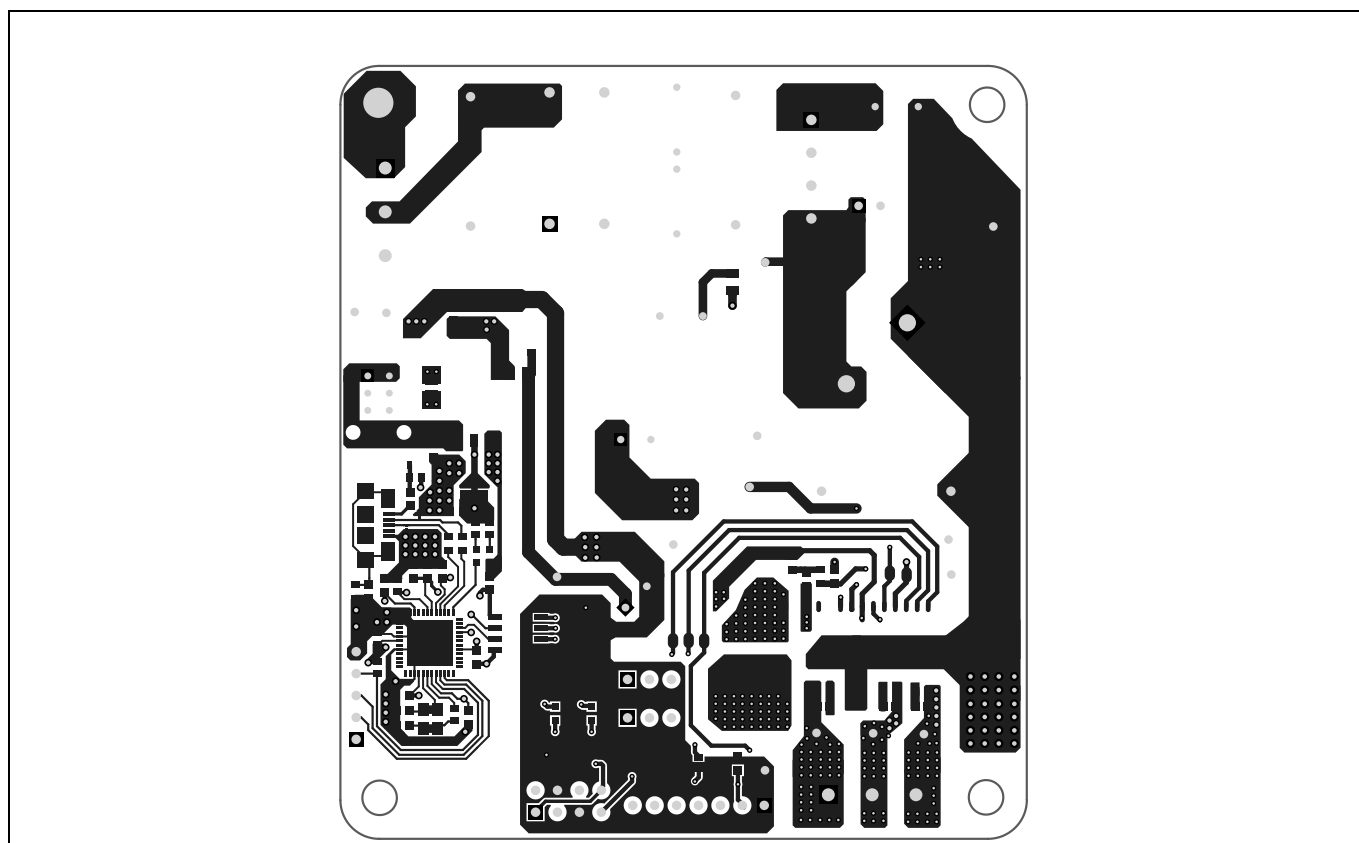
## PCB layout

Figure 27 shows the bottom assembly print of the evaluation board.



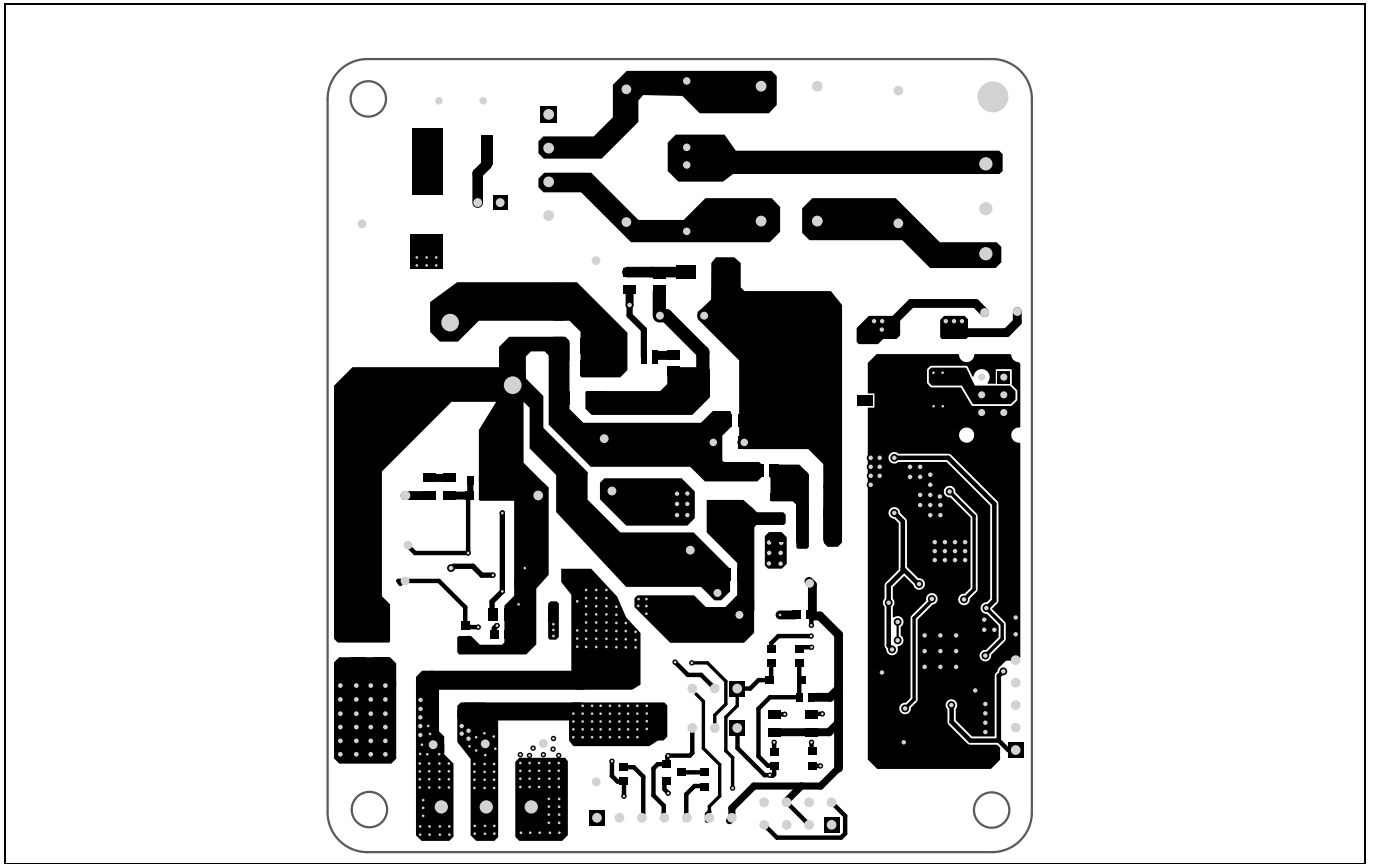
**Figure 27 Bottom assembly print of the EVAL-IMI111T evaluation board**

The top layer of the PCB is shown in Figure 28.



**Figure 28 Top layer of EVAL-IMI111T**

Figure 29 shows the bottom layer routing of the PCB.



**Figure 29** Bottom layer of EVAL-IMI111T

## Application diagram

## 9 Application diagram

### 9.1 Application diagram

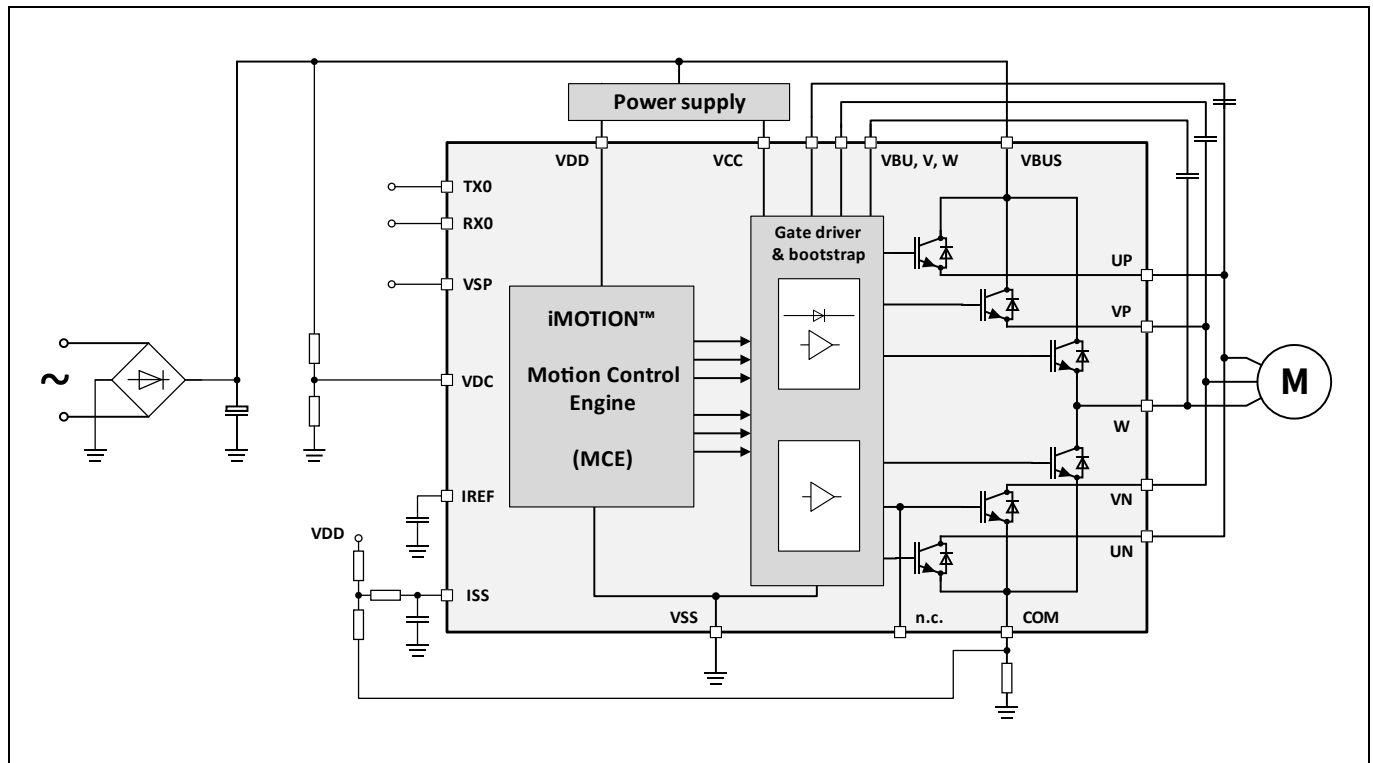


Figure 30 Block diagram of an application using IMI111T

**Bill of materials**

## 10 Bill of materials

The complete bill of material (BOM) is available in the download section of Infineon's homepage. A log in is required to download this material.

**Table 11 BOM of the most important/critical parts**

| No. | Qty. | Part description  | Designator | Part Number                | Manufacturer          |
|-----|------|---|------------|----------------------------|-----------------------|
| 1   | 1    | Glass Passivated Bridge Rectifier   | BR1        | KBP206G                    | Diodes Incorporated   |
| 2   | 2    | CAP / FILM / 100nF / 630V / 10% / MKP (Metallized Polypropylene) / -40 °C to 105 °C / 15.00mm C X 0.80mm W 18.00mm L X 6.00mm T X 13.00mm H / THT / - | CX1, CX2   | 890324025017CS             | Wurth Elektronik      |
| 3   | 2    | CAP / CERA / 2.2nF / / 20% / E (JIS) / -40 °C to 125 °C / 7.50mm C X 0.60mm W 8.00mm L X 4.00mm T X 11.00mm H / - / -                                 | CY1, CY2   | DE2E3SA222MN3AX02F         | MuRata                |
| 4   | 2    | Surface Mount Ultrafast Rectifier 1.0A/600V   | D1, D2     | US1J-E3/61T                | Vishay                |
| 5   | 2    | Horizontal Cable Entry With Rising Cage Clamp - WR-TBL, 3Pins   | J1, J3     | 691216510003S              | Wurth Elektronik      |
| 6   | 2    | WR-PHD Pin Header   | J2, J4     | 61300311121                | Wurth Elektronik      |
| 7   | 1    | WR-PHD 2.54 mm Pitch, THT, 7 Pin Header   | J5         | 61300711121                | Wurth Elektronik      |
| 8   | 1    | Connector, 2.54mm pitch, 8pins, Board to Board, Through Hole  | J7         | 61300821121                | Wurth Elektronik      |
| 9   | 1    | IND / STD / 1mH / 4.8A / - / -55 °C to 105 °C / 20mR / THT / Inductor, THT, 4 Pins, 19.304 mm L X 16.129 mm W X 22.86 mm H body / THT / -             | L1         | 8103-RC                    | Bourns                |
| 10  | 1    | Radial Lead RF Choke  | L100       | RL875-222K-RC              | Bourns                |
| 11  | 1    | chip ferrite beads BLM series   | L101       | BLM18PG600SN1D             | MuRata                |
| 12  | 1    | HEXFET Power MOSFET VDS 30V   | Q1         | IRLML2030TRPbF             | Infineon Technologies |
| 13  | 1    | Surface-mount compact crystal unit suitable for automotive  | Q101       | NX3225GA-12.000M-STD-CRG-2 | Nihon Dempa Kogyo     |



**Bill of materials**

| No. | Qty. | Part description  | Designator   | Part Number                | Manufacturer               |
|-----|------|---|--|----------------------------|----------------------------|
| 14  | 1    | RES / STD / 250mR / 250mW / 1% / 600ppm/K / -55 °C to 155 °C / 1206 / SMD / -                                   | RS1  | RL1206FR-070R25L           | Yageo                      |
| 15  | 1    | RES / NTC / 15R / 1.4W / - / - / -55 °C to 170 °C / 5.00mm C X 0.60mm W 8.50mm L X 5.00mm T X 13.00mm H / - / - | RT1  | B57153S0150M000            | TDK Corporation            |
| 16  | 13   | Test Point THT, White   | TP1, TP2, TP6, TP7, TP19, TP22, TP23, TP25, TP27, TP28, TP29, TP30, TP31 | 5002                       | Keystone Electronics Corp. |
| 17  | 1    | Lowest Component Count, Energy-Efficient Off-Line Switcher IC, 120mA MDCM in 230 V <sub>AC</sub>                | U1   | LNK304DG                   | Power Integrations         |
| 18  | 2    | Voltage Regulator, 3.3 V Output   | U3, U102   | IFX1117ME V33              | Infineon Technologies      |
| 19  | 1    | IMI111T-026H / IMI111T-046H iMOTION™ IPM for motor control  | U4   | IMI111T-026H/ IMI111T-046H | Infineon Technologies      |
| 20  | 1    | 80 MHz XMC4200 MCU with 256 kb Program Memory, 40 kb SRAM, 3.3 V, -40 to 85 deg C, PG-VQFN-48, Green            | U101   | XMC4200-Q48F256 BA         | Infineon Technologies      |
| 21  | 1    | Low-Power Dual-Channel Digital Isolator   | U103   | SI8621EC-B-IS              | Silicon Labs               |
| 22  | 2    | Bi-directional TVS Protection Device, 8V, 7pF   | V101, V102   | ESD237-B1-W0201            | Infineon Technologies      |
| 23  | 1    | Medium Power AF Schottky Diode  | V103   | BAS3010A-03W               | Infineon Technologies      |
| 24  | 2    | Jumper, 1x2-Positions, Pitch 2,54mm, Body 5,08x2,54mm, black, Au, without handle                                | X1, X2   | SNT-100-BK-G               | Samtec                     |

**Bill of materials**

| No. | Qty. | Part description   | Designator | Part Number     | Manufacturer      |
|-----|------|--|------------|-----------------|-------------------|
| 25  | 1    | Micro-USB 2.0 Standard,<br>Type AB, Bottom Mount,<br>Shell SMT | X101       | ZX62-AB-5PA(31) | Hirose Connectors |

## 11 References and appendices

### 11.1 Abbreviations and definitions

**Table 12** Abbreviations

| Abbreviation | Meaning                      |
|--------------|------------------------------|
| CE           | Conformité Européenne        |
| EMI          | Electromagnetic interference |
| UL           | Underwriters Laboratories    |

### 11.2 Additional information

To initiate testing, customers can order the iMOTION™ link. Details are provided in Table 13.

Infineon components on the board are also listed in Table 13. Customers can visit the corresponding webpage for more information.

**Table 13** Additional information on tools and Infineon components

| Base part number              | Package     | Standard pack |          | Orderable part number |
|-------------------------------|-------------|---------------|----------|-----------------------|
|                               |             | Form          | Quantity |                       |
| <a href="#">iMOTION™ Link</a> |             | Container     | 1        | IMOTIONLINK           |
| <a href="#">IMI111T-026H</a>  | PG-DSO-22-1 | Tape and reel | 1500     | IMI111T026HXUMA1      |
| <a href="#">IMI111T-046H</a>  | PG-DSO-22-1 | Tape and reel | 1500     | IMI111T046HXUMA1      |

### 11.3 References

- [1] Infineon Technologies AG. [Datasheet of IMI111T-026H/-046H v1.1](#)
- [2] Infineon Technologies AG. [iMOTION™ – MCE – Software Reference Manual v1.3](#)
- [3] Infineon Technologies AG. [Functional Reference Manual iMOTION™ Motion Control Engine v1.1](#)
- [4] Infineon Technologies AG. [iMOTION™ Solution Designer v1.1](#)
- [5] Infineon Technologies AG. [How to Use UART Interface on IMM101T and IMI111T v1.0](#)

## 12 Revision history

| Document version | Date of release | Description of changes   |
|------------------|-----------------|--|
| V 1.0            | 2022/6/8        | Initial version  |
| V 2.0            | 2022/9/13       | Changed description of section 7.2 and added section 7.3                 |
| V2.1             | 2022/10/20      | Changed related contents for removing 3.3 V supply from onboard debugger |

**Trademarks**

All referenced product or service names and trademarks are the property of their respective owners.

**Edition 2022-12-9**

**Published by**

**Infineon Technologies AG**

**81726 Munich, Germany**

**© 2023 Infineon Technologies AG.**

**All Rights Reserved.**

**Do you have a question about this document?**

**Email:** [erratum@infineon.com](mailto:erratum@infineon.com)

**Document reference**

**UG-2022-06**

For further information on the product, technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies office ([www.infineon.com](http://www.infineon.com)).

**WARNINGS**

Due to technical requirements products may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies office.

Except as otherwise explicitly approved by Infineon Technologies in a written document signed by authorized representatives of Infineon Technologies, Infineon Technologies' products may not be used in any applications where a failure of the product or any consequences of the use thereof can reasonably be expected to result in personal injury.