

EVAL-6ED2231S12TM1 User Guide

1200 V SOI gate driver 6ED2231S12T evaluation board

About this document

Scope and purpose

This user guide provides an overview of the evaluation board EVAL-6ED2231S12TM1 including its main features, key components, pin assignments, and mechanical dimensions. This guide also describes how to run a brushless direct current (BLDC) motor.

EVAL-6ED2231S12TM1 is a power evaluation board that includes an M1 connector, one EasyPACK™ 1B 1200 V CoolSiC™ MOSFET three-phase module, and one three-phase silicon-on-insulator (SOI) gate driver for motor drive applications. In combination with either EVAL-M1-101T or other control board with compatible M1 connectors, the EVAL-6ED2231S12TM1 features and demonstrates Infineon's CoolSiC™ MOSFET module and SOI gate driver technology for motor drives.

EVAL-6ED2231S12TM1 was developed to support users during their first steps in designing applications with Infineon's EasyPACK™ 1B CoolSiC™ MOSFET module and the three-phase gate driver.

Intended audience

This document is intended for all technical specialists who have a knowledge of motor control and electronic converters with several kilowatts of power. The board must be used only under laboratory conditions.

Evaluation board

EVAL-6ED2231S12TM1 is designed to evaluate the 1200 V SOI three-phase gate driver 6ED2231S12T along with the EasyPACK™ 1B 1200 V CoolSiC™ MOSFET module FS55MR12W1M1H_B11.

This board will be 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.

Ordering information

Base part number	Package	Standard pack		Orderable part number
		Form	Quantity	
EVAL-6ED2231S12TM1	MADK EVAL	Boxed	1	EVAL6ED2231S12TM1TOBO1
6ED2231S12T	PG-DSO-24	Tape and Reel	1000	6ED2231S12TXUMA1
EVAL-M1-101T	MADK EVAL	Container	1	EVALM1101TTOBO2
FS55MR12W1M1H_B11	AG-EASY1BM	Tray	24	FS55MR12W1M1HB11NPSA1
ICE5QSAG	PG-DSO-8	Tape and Reel	2500	ICE5QSAGXUMA1
IMBF170R1K0M1	PG-TO263-7	Tape and Reel	1000	IMBF170R1K0M1XTMA1
IFX25001TF V33	PG-TO252-3	Tape and Reel	2500	IFX25001TFV33ATMA2

Important notice

Important notice

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Safety precautions

Safety precautions

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

Table 1 Safety precautions

	Warning: The DC link potential of this board is up to 800 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.
	Warning: 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.
	Warning: 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.
	Warning: 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.
	Caution: 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.
	Caution: 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.
	Caution: 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.
	Caution: 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.
	Caution: 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.

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The board at a glance

1 The board at a glance

The evaluation board EVAL-6ED2231S12TM1 provides a DC input and a three-phase output for power motors. It contains the gate driver IC 6ED2231S12T, the EasyPACK™ 1B module FS55MR12W1M1H_B11, a heat sink, bus capacitors, a single shunt for current sensing, a voltage divider for DC-link voltage measurement, and other peripheral circuits.

1.1 Delivery content

The EVAL-6ED2231S12TM1 evaluation board is delivered along with a daughter board (EVAL-6ED2231S12TM1D) for the gate driver, and an iMOTION™ 2.0 M1 interface connector.

The package also contains a quasi-resonant, pulse-width modulation (PWM) controller; a CoolSiC™ MOSFET-based auxiliary power supply to provide 18 V and 3.3 V; a single shunt for current sensing and overcurrent protection; and a voltage divider for DC-link voltage measurement. The board can be operated directly with the required DC power supply without any additional components.

1.2 Block diagram

Figure 1 shows a typical application diagram of EVAL-6ED2231S12TM1 for driving a BLDC motor. The system adopts a single-shunt configuration, which is prevalent for current BLDC motor drive applications.

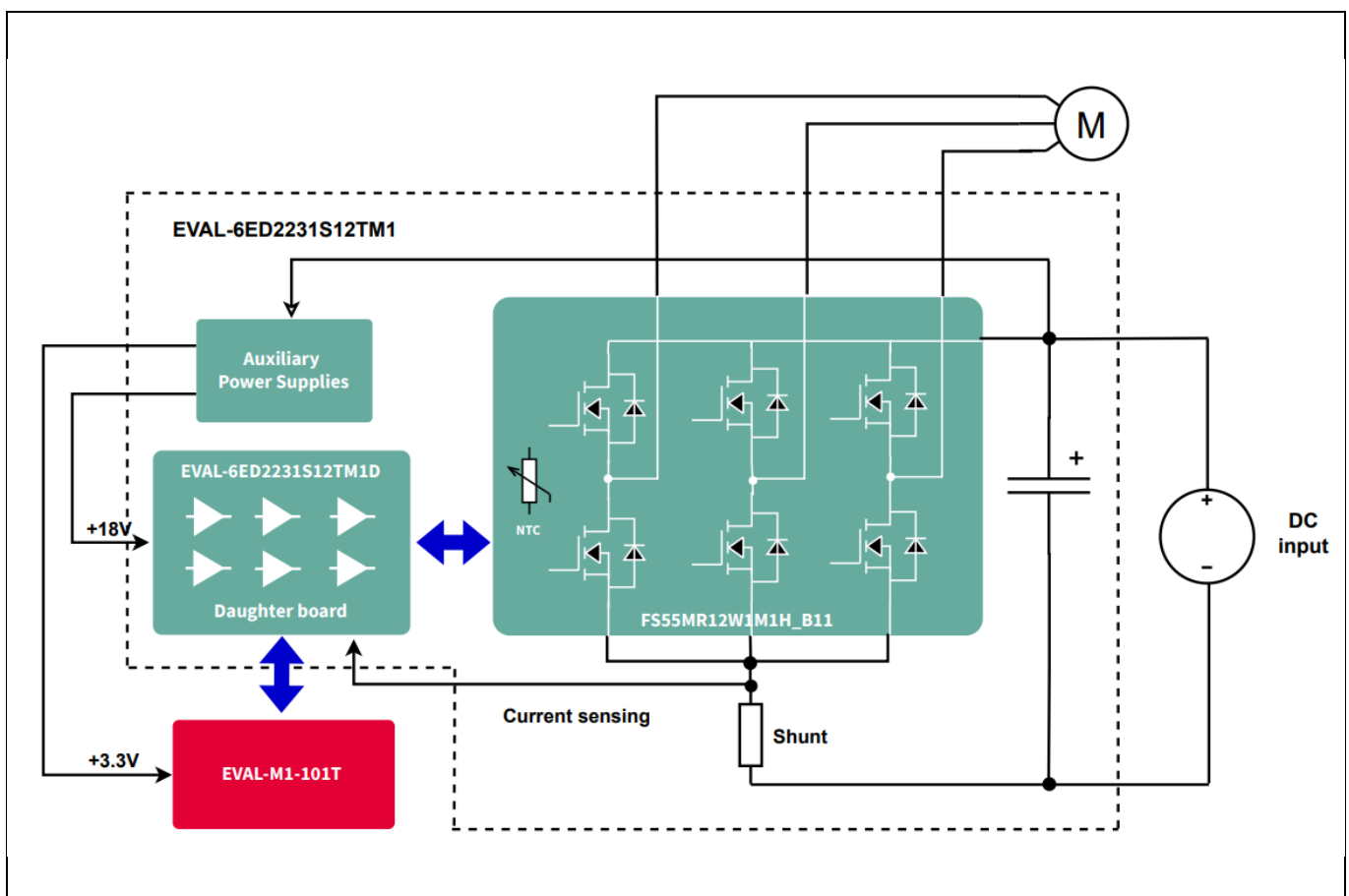


Figure 1 Typical application block diagram of EVAL-6ED2231S12TM1

The functional blocks of EVAL-6ED2231S12TM1 are presented in Figure 2 and Figure 3.

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1200 V SOI gate driver 6ED2231S12T evaluation board

The board at a glance

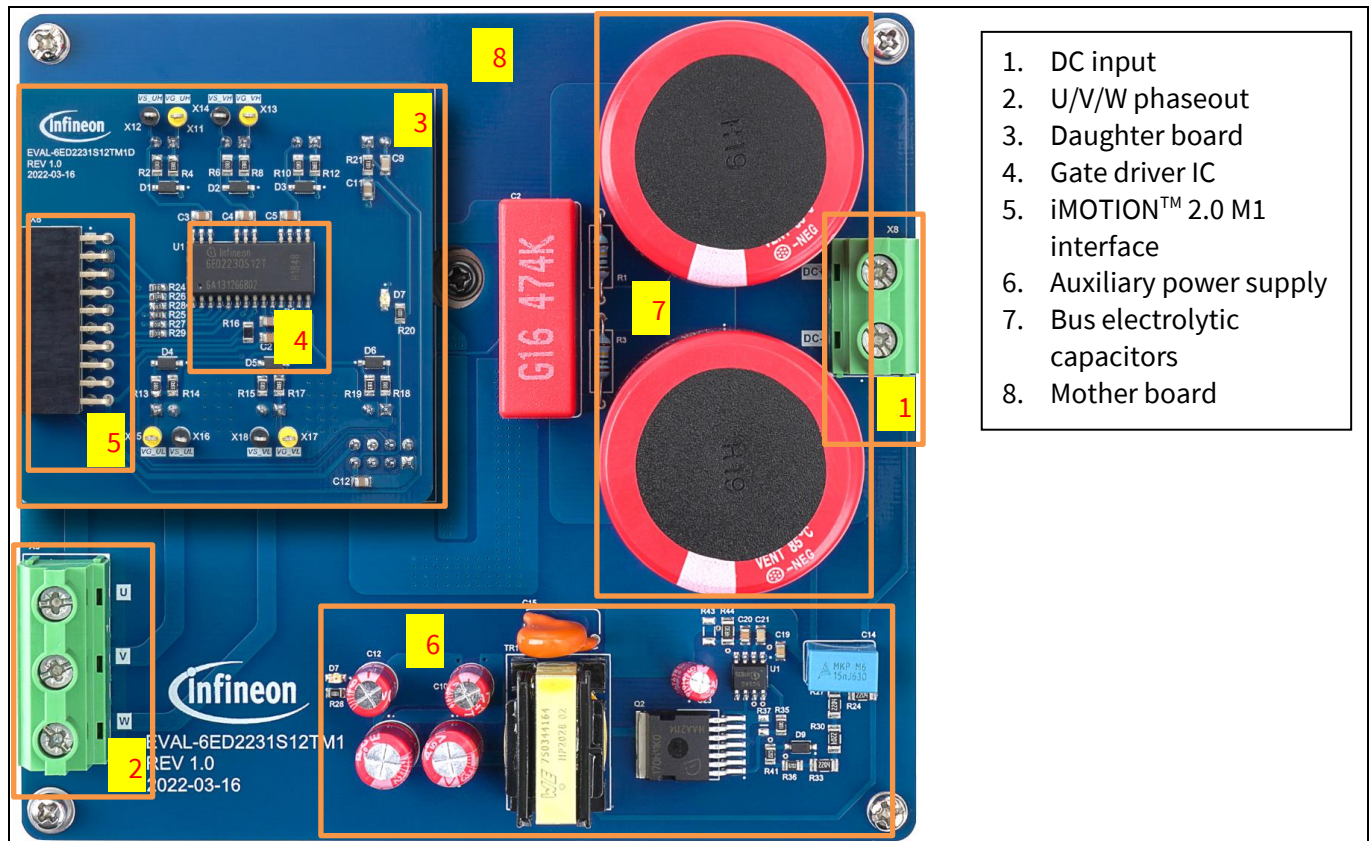


Figure 2 Functional blocks of EVAL-6ED2231S12TM1 (top view)

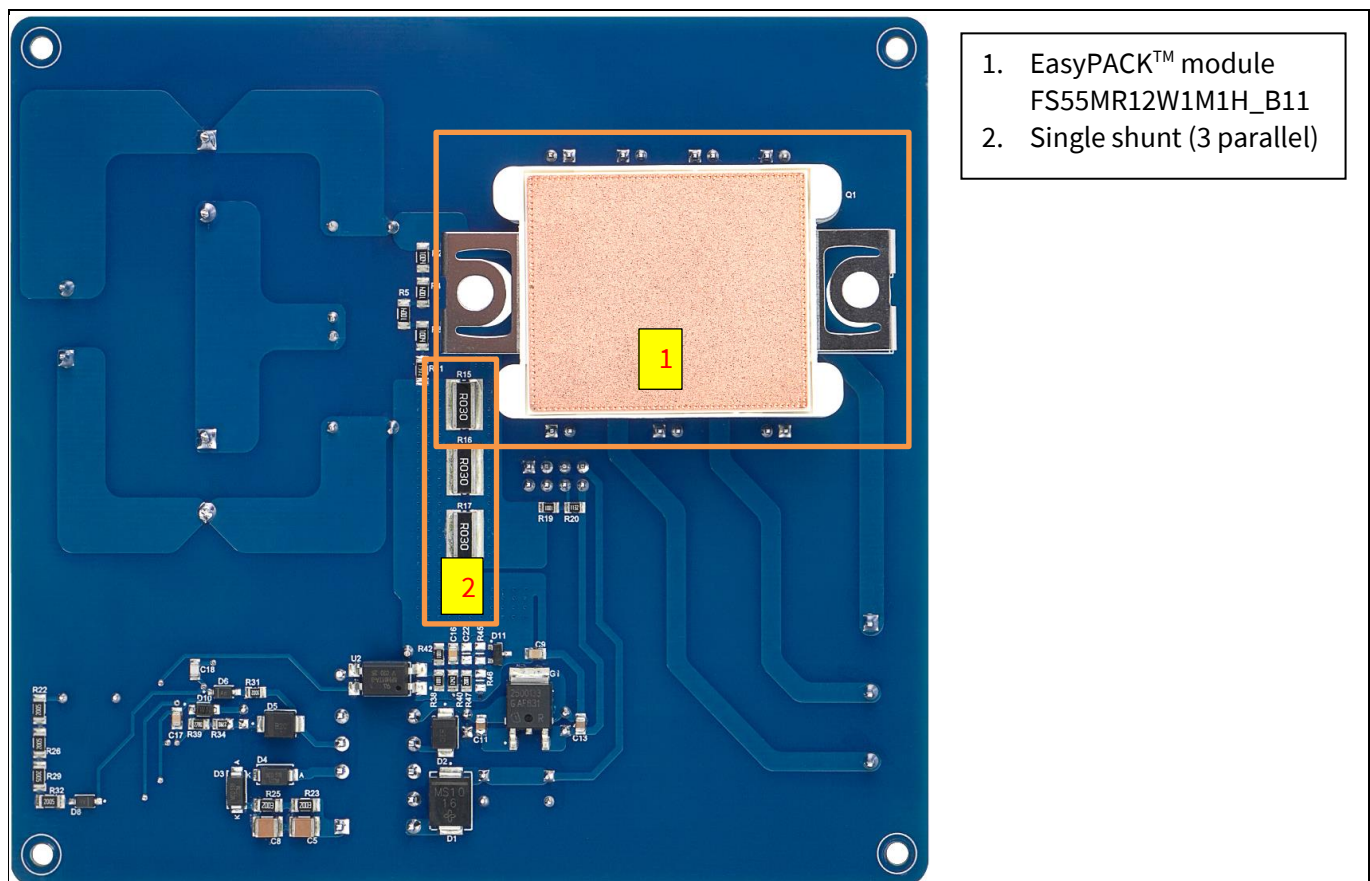


Figure 3 Functional blocks of EVAL-6ED2231S12TM1 (bottom view)

The board at a glance

1.3 Main features

The main features of EVAL-6ED2231S12TM1 include:

- Nominal DC input voltage of 510 V
- Design for maximum 5 kW motor power output
- Single shunt for current sensing
- Sensing of DC-link voltage
- Internal negative temperature coefficient (NTC) thermistor for overtemperature protection
- +18 V and +3.3 V auxiliary power supplies on the board
- M1 interface compatible with the iMOTION™ control board

1.4 Board parameters and technical data

The key specifications of EVAL-6ED2231S12TM1 are listed in Table 2.

Table 2 Specifications of EVAL-6ED2231S12TM1

Parameter	Symbol	Conditions	Value			Unit
			Min.	Nom.	Max.	
Input						
Input voltage	V _{IN}	DC voltage	120	510	720	V
Input current	I _{IN}	Input current	–	–	10	A
Output						
Output current	I _{OUT}	RMS phaseout current	–	–	15	A
Output power	P _{OUT}	Additional heat dissipation is needed (e.g. forced air cooling)	–	–	5	kW
Overcurrent protection	I _{OCP}	Peak phaseout current	–	–	25.2	A
Thermal protection						
NTC overtemperature threshold	V _{TH}	Configuration in MCEWizard	1.09	2.75	–	V
			100	25	–	°C
Switching frequency						
Inverter carrier frequency	F _{SW}		–	16	–	kHz
Auxiliary power supply						
Gate driver power supply	V _{CC}		–	18	–	V
Controller power supply			–	3.3	–	V
System environment						
Ambient temperature		With adequate cooling method	–	25	–	°C
PCB characteristics						
Dimensions	L	Length	–	130	–	mm
	W	Width	–	120	–	mm
	H	Height	–	60	–	mm
Layer			–	2	–	

The board at a glance

Parameter	Symbol	Conditions	Value			Unit
			Min.	Nom.	Max.	
Input						
PCB thickness			–	1.6	–	mm
Copper thickness			–	1	–	oz.
Weight		Weight of the entire PCB assembly	–	1000	–	g
Material		FR-4, RoHS-compliant				

2 System and functional description

2.1 Getting started with EVAL-6ED2231S12TM1

To run the motor system, a combination of the iMOTION™ power board EVAL-6ED2231S12TM1 and a matching iMOTION™ control board (e.g. EVAL-M1-101T) are required. This chapter explains how to set up the system and get started with the iMOTION™ development platform.

The power board EVAL-6ED2231S12TM1 can run a BLDC motor by connecting to the iMOTION™ 2.0 control board EVAL-M1-101T through an M1 interface. The system connection is shown in Figure 4, and the test results are listed in section 4.1.

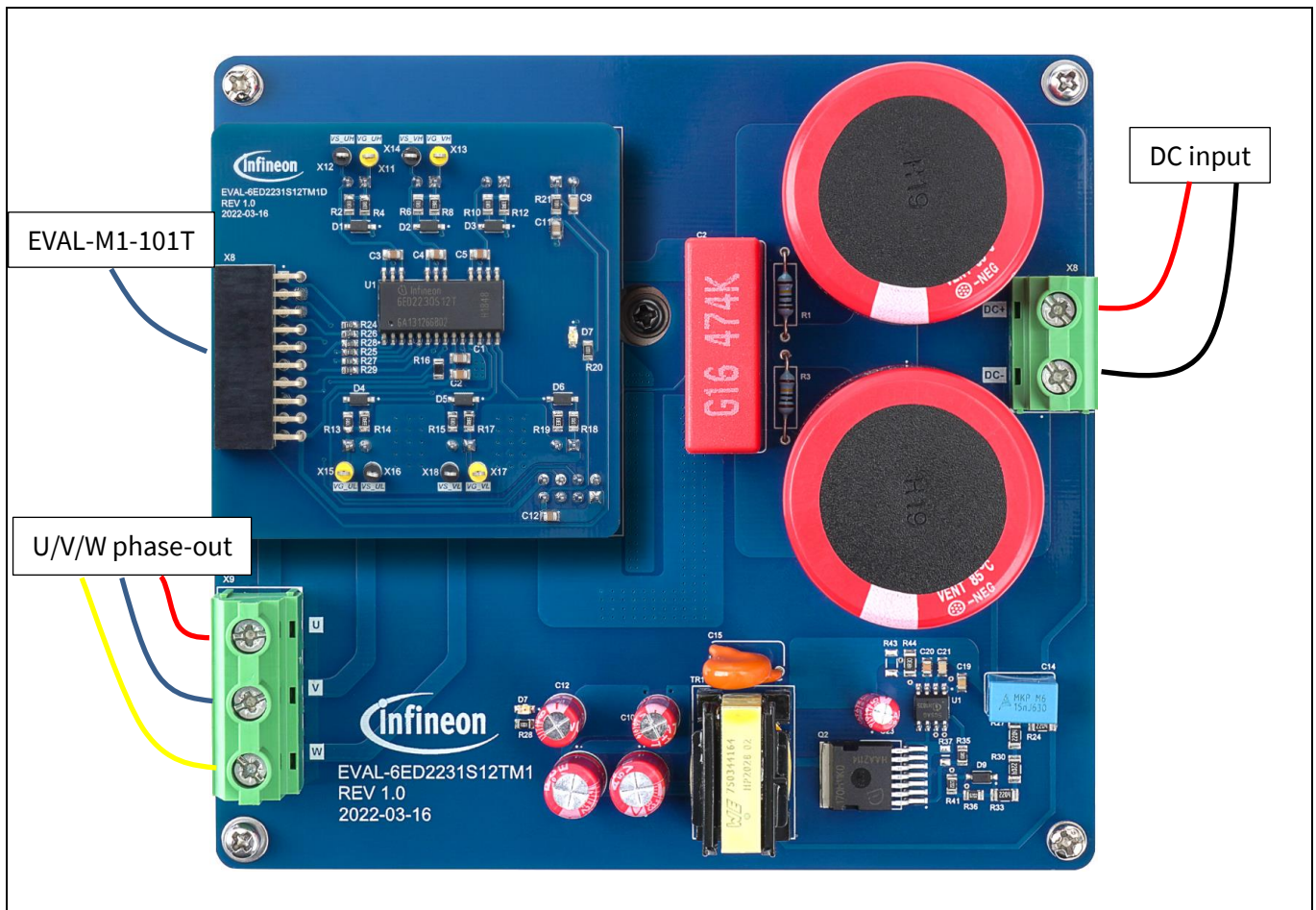


Figure 4 The system connection for running a BLDC motor

2.1.1 The iMOTION™ control board

You can order the Infineon control board EVAL-M1-101T from <https://www.infineon.com/cms/en/product/evaluation-boards/eval-m1-101t> and download the latest IMC101T-T038 MCE Software Package from www.infineon.com/imotion-software.

After obtaining EVAL-M1-101T and the latest software, connect your PC to the control board via a USB cable to program and tune it.

1. Connect EVAL-M1-101T's M1 20-pin interface connector J2 to the daughter board X8.
2. In the MCEWizard enter the system and operating parameters of the target motor and the hardware parameters of the evaluation board. This data is used for calculating the digital parameter set of the controller, representing the complete motor drive system.

System and functional description

3. Go to the Verify & Save page and click **Calculate Parameters**. Then, save the drive parameter set into your project directory by clicking **Export to MCEDesigner file (.txt)** (see Figure 6). This saved drive system parameter file will be used later by the MCEDesigner. Refer to Section 2.1.4 or the MCEWizard user guide for more information.
4. Connect motor phase outputs (X9 on the mother board) to the motor.
5. Connect DC power to the power input connector (X8 on the mother board), then power on the system.
6. Start the MCEDesigner tool.
7. Click **File > Open** to open the MCEDesigner default configuration file (.irc) for the IMC101T-T038 controller (IMC101T_Vxxx.irc). The IMC101T_Vxxx.irc file is included in the IMC101T-T038 MCE software package.
8. The MCEDesigner should automatically connect to the EVAL-M1-101T control board using the default COM port (indicated by a green circle next to the “COMx Up” status in the bottom frame of the MCEDesigner GUI). If the connection cannot be established, change the COM port:
 - a) Open the System Page window.
 - b) Click **Preferences > Connection > Connect using**.
 - c) Choose one of the other available COM ports from the drop-down list.
9. Program the system parameters into the internal SRAM of the iMOTION™ IC using the following steps:
 - a. Click **Tools > Programmer** and select **Program Parameters**.
 - b. Browse and select the System Drive Parameters file created in step 3. See Section 2.1.4 for more information.
10. Start the motor by clicking the green traffic light button in the control bar. To stop the motor click the red traffic light button in the control bar.

2.1.2 iMOTION™ development tools and software

The EVAL-6ED2231S12TM1 evaluation board can run a BLDC motor when connected to an external control board EVAL-M1-101T. Users must configure the iMOTION™ development tool and software according to the system and BLDC motor parameters.

The MCEDesigner, MCEWizard, and supported files can be downloaded from <http://www.infineon.com/imotion-software>.

2.1.3 MCEWizard setup overview

Use the MCEWizard to configure the parameters for the evaluation board or motor. Figure 5 shows the Welcome page of the MCEWizard. Here, users can select the control board or power board from a drop-down list. Infineon releases new control and power boards regularly. Therefore, it is possible that some of the latest power boards have not been pre-configured in the MCEWizard tool and cannot be selected from the drop-down menu. In that case, users can select another (as similar as possible) power board and follow the setup steps in the MCEWizard by entering parameters specific to the power board chosen. Please refer to the application note of the corresponding power board for additional information.

After selecting the modular application design kit (MADK) control board and the power board, click **Next** in the right-hand bottom corner of the Welcome page to start the MCEWizard system setup process.

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1200 V SOI gate driver 6ED2231S12T evaluation board

System and functional description

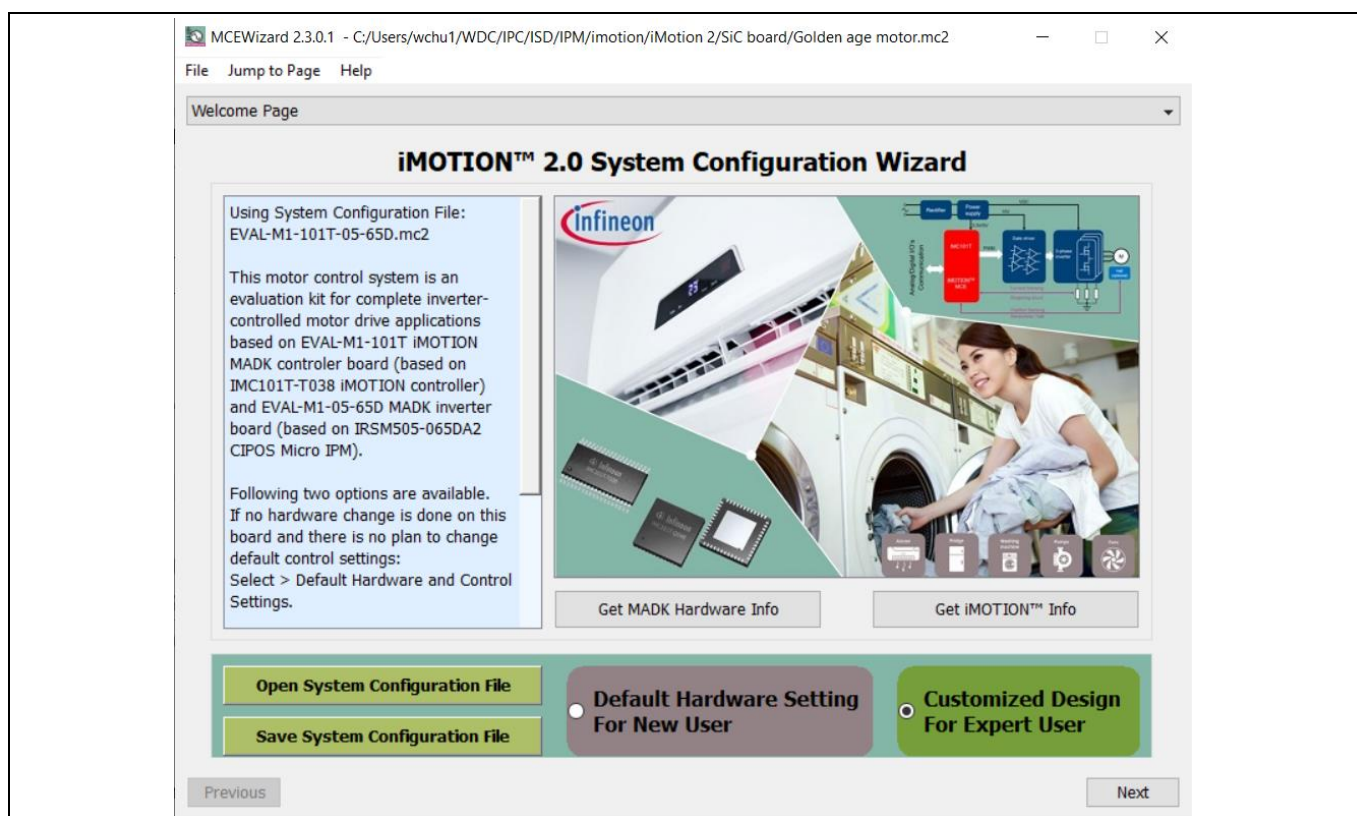


Figure 5 Welcome page of the MCEWizard

The iMOTION™ system enables users to easily test different combinations of control and power boards with their motors. Users should be familiar with system-level parameters related to the motor used. There are a limited number of parameters specific to the control board or power board hardware. Table 3 lists the hardware parameters specific to EVAL-6ED2231S12TM1 power board for MCEWizard setup. Similar tables are available for each control board in its application note. A combination of data in this table and the corresponding table of the control board provides sufficient information to quickly set up the motor drive system.

Table 3 MCEWizard setup overview table

Parameter	Value
Control board selecting	EVAL-M1-101T for example
Motor 1 shunt configuration	Single shunt
Controller supply voltage	+3.3 V
Max DC bus voltage	720 V
DC bus sensing high resistor	4000 kΩ
DC bus sensing low resistor	13 kΩ
NTC temperature shutdown value	Refer to the control board's application note
Gate sense low-side devices	High is true
Gate sense high-side devices	High is true
Motor 1 current input scaling	Calculated in the corresponding section of the control board's application note

After all the MCEWizard questions are answered, the Verify & Save Page opens (see Figure 6.)

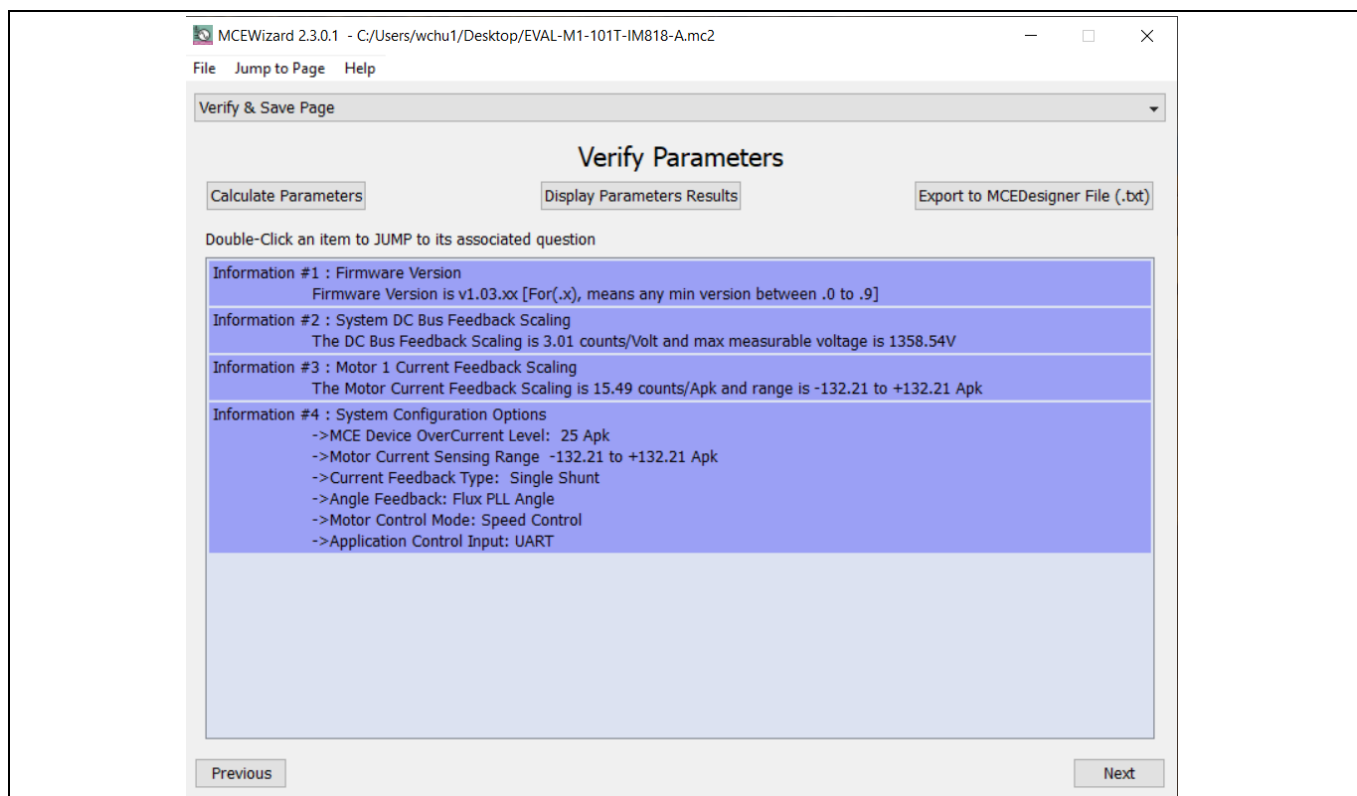


Figure 6 Verify and save page of the MCEWizard

Click **Calculate Parameters** and then **Export to MCEDesigner File (.txt)** to save the parameter file. This file will be used by the MCEDesigner in the next steps.

2.1.4 MCEDesigner setup overview

The MCEDesigner is a user interface to access or debug the control board. Open the MCEDesigner and then open the IMC101T_xx.irc file. The main display page for EVAL-M1-101T opens, as shown in Figure 7.

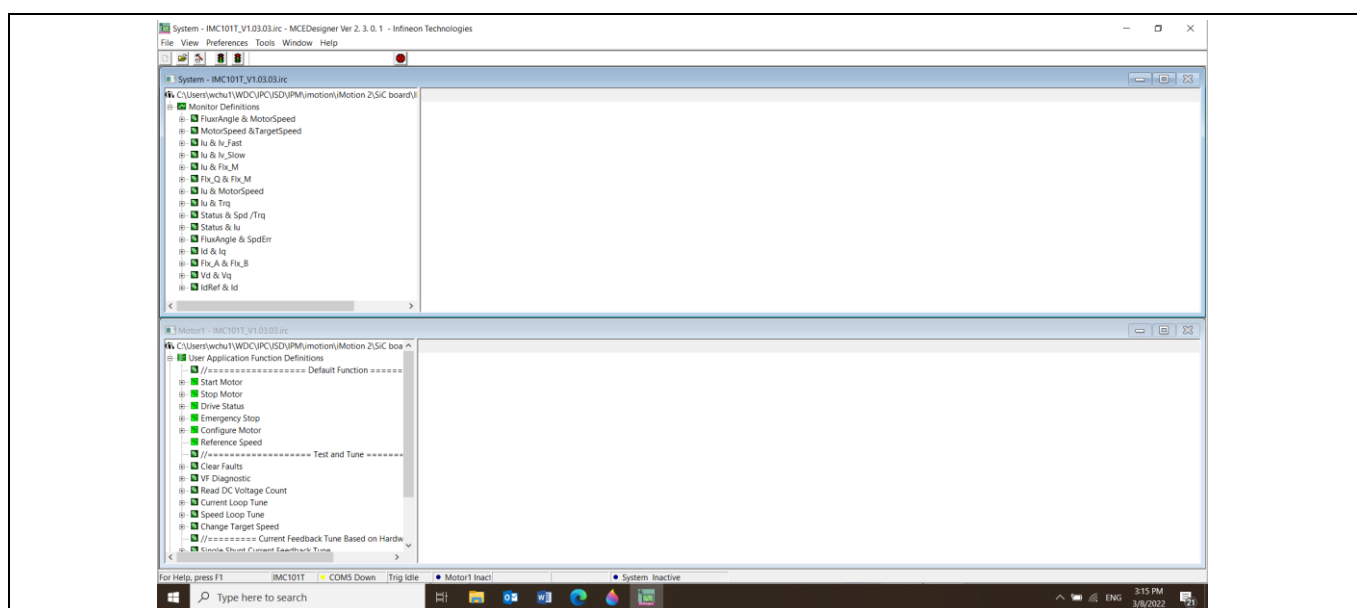


Figure 7 MCEDesigner's main display for EVAL-M1-101T

The main features of 6ED2231S12T include:

- Infineon's thin-film SOI technology
- Fully operational up to +1200 V
- Integrated ultra-fast bootstrap diode
- Floating channel designed for bootstrap operation
- Output source/sink current capability of +0.35 A/-0.65 A
- Tolerant to negative transient voltage up to -100 V (pulse width up to 700 nanoseconds) provided by the SOI technology
- Undervoltage lockout for both channels
- Compatible with 3.3 V, 5 V, and 15 V input logic
- Overcurrent protection with $\pm 5\%$ ITRIP threshold
- Fault reporting, automatic fault clear, and enable functions on the same pin (RFE)
- Matched propagation delay for all channels
- Integrated 460 nanoseconds of dead time
- Shoot-through (cross-conduction) protection

Table 4 Absolute maximum ratings of 6ED2231S12T

Symbol	Definition	Min.	Max.	Units
V_{CC}	Low-side supply voltage	-0.3	25	V
V_{IN}	Logic input voltage (LIN, HIN, RFE, ITRIP)	$V_{SS} - 5$	$V_{CC} + 0.3$	
$V_{B1,2,3}$	High-side floating well supply voltage	-0.3	1225	
$V_{S1,2,3}$	High-side floating well supply return voltage	$V_{B1,2,3} - 25$	$V_{B1,2,3} + 0.3$	
$V_{HO1,2,3}$	Floating gate drive output voltage	$V_{S1,2,3} - 0.3$	$V_{B1,2,3} + 0.3$	
$V_{LO1,2,3}$	Low-side output voltage	-0.3	$V_{CC} + 0.3$	
V_{SS}	Logic ground	$V_{CC} - 25$	$V_{CC} + 0.3$	
dV_S/dt	Allowable V_S offset supply transient relative to COM	—	50	V/ns
P_D	Package power dissipation @ $T_A \leq +25^\circ\text{C}$	—	1.3	W
R_{thJA}	Thermal resistance, junction to ambient	—	75	$^\circ\text{C}/\text{W}$
T_J	Junction temperature	—	150	$^\circ\text{C}$
T_S	Storage temperature	-55	150	
T_L	Lead temperature (soldering, 10 seconds)	—	300	

System and functional description

2.2.2 Overview of FS55MR12W1M1H_B11

The FS55MR12W1M1H_B11 is an EasyPACK™ 1B 1200 V / 52.9 mΩ (typical) six-pack module with CoolSiC™ MOSFET, NTC, and PressFIT contact technology.

Figure 9 shows the circuit diagram of FS55MR12W1M1H_B11. For more information about the module, please refer to the datasheet of FS55MR12W1M1H_B11.

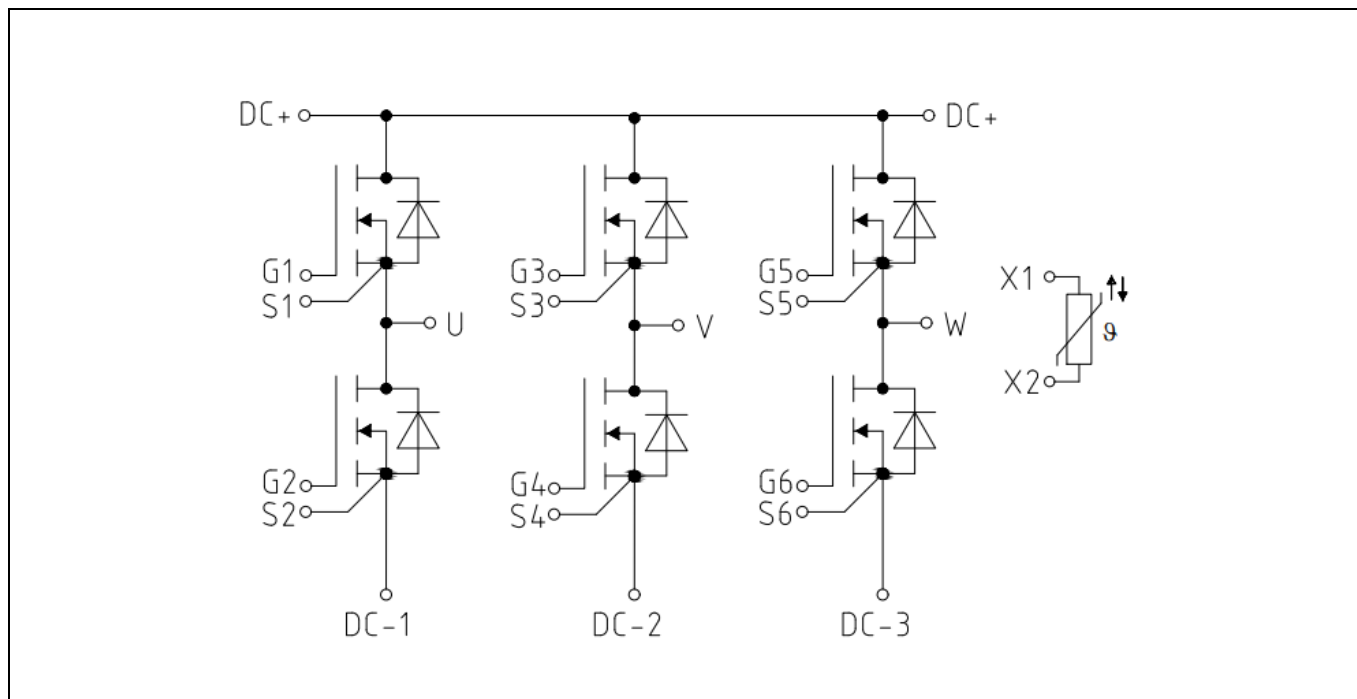


Figure 9 **Circuit diagram**

The main features of FS55MR12W1M1H_B11 include:

- High current density
- Best-in-class switching and conduction losses
- Low inductive design
- Integrated NTC temperature sensor
- PressFIT contact technology
- RoHS-compliant modules

2.2.3 Overview of ICE5QSAG

The latest, 5th generation quasi-resonant fly-back pulse width modulation (PWM) controller ICE5QSAG offers high performance and comprehensive suite of protection to increase system robustness.

Figure 10 shows the functional block diagram of ICE5QSAG. For more information regarding the PWM controller, please refer to the datasheet of ICE5QSAG.

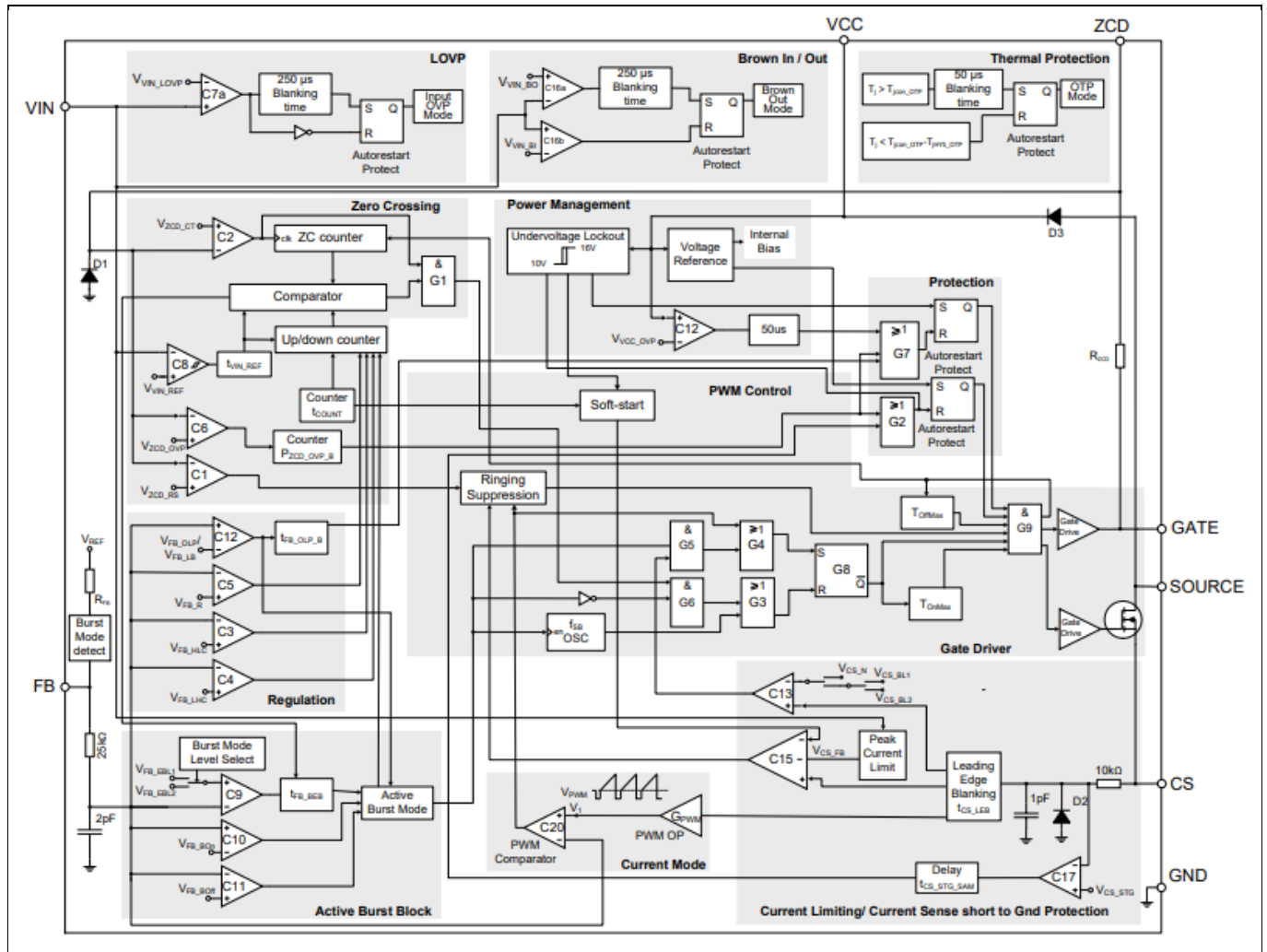


Figure 10 Circuit diagram

The main features of ICE5QSAG include:

- Novel quasi-resonant operation and proprietary implementation for low EMI
- Enhanced active burst mode with selectable entry and exit standby power
- Active burst mode to reach the lowest standby power
- Fast startup achieved through cascade configuration
- Digital frequency reduction for better overall system efficiency
- Robust line protection with input overvoltage protection and brownout protection
- Comprehensive protection
- Lead-free plating, halogen free mold compound, RoHS compliant

2.2.4 Overview of IMBF170R1K0M1

IMBF170R1K0M1 is a CoolSiC™ 1700 V, 1000 mΩ SiC MOSFET in a TO-263-7 high creepage package; optimized for fly-back topologies. It can be used in auxiliary power supplies connected to DC-link voltages from 600 V up to 1000 V in numerous power applications. For more information regarding the power device, please refer to the datasheet of IMBF170R1K0M1.

The main features of IMBF170R1K0M1 include:

- Revolutionary semiconductor material—silicon carbide
- Optimized for fly-back topologies
- 12 V/0 V gate-source voltage compatible with most fly-back controllers
- Very low switching losses
- Benchmark gate threshold voltage, $V_{GS(th)} = 4.5 \text{ V}$
- Fully controllable dV/dt for EMI optimization

System design

3 System design

This chapter covers the hardware design of EVAL-6ED2231S12TM1 in detail. Users can modify the circuit or re-select the component values based on actual applications in the field.

3.1.1 DC-link voltage measurement

Bus capacitors should be large enough to stabilize the bus voltage. The resistors R1 and R3 are used to balance the voltage on the electrolytic capacitors in series as shown in Figure 11.

Note: The resistor R11 is soldered on the mother board of EVAL-6ED2231S12TM1. Therefore, the 13.3 k Ω pull-down resistor located on the EVAL-M1-101T control board must be removed.

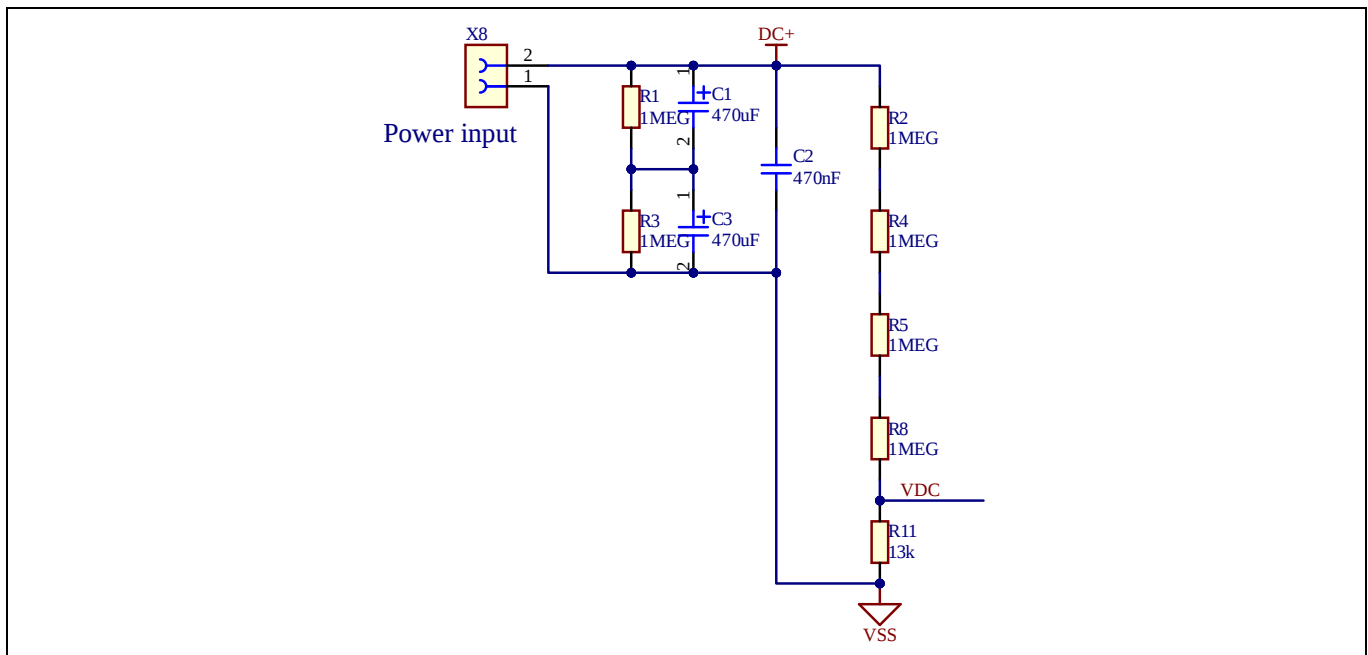


Figure 11 Bus capacitor configuration and DC bus sensing

3.1.2 Inverter section using FS55MR12W1M1H_B11

The inverter section is implemented using FS55MR12W1M1H_B11 as shown in Figure 12. It is a three-phase inverter bridge section with Infineon's CoolSiC™ SiC MOSFET. R15/R16/R17 (in parallel) are single shunt for current sensing.

System design

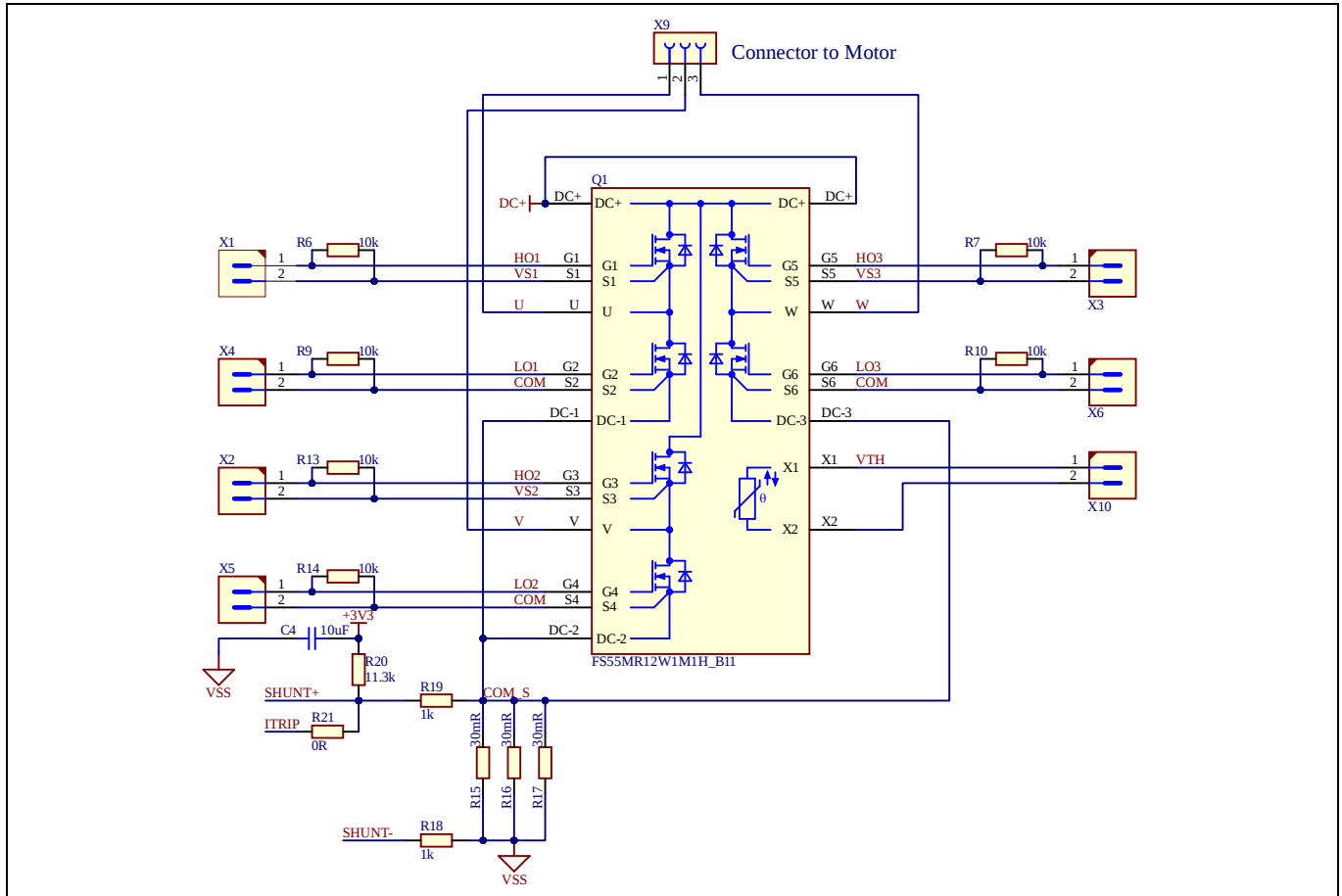


Figure 12 The diagram of the inverter section

3.1.3 Drive circuit with 6ED2231S12T

A dedicated daughter board for the three-phase gate driver 6ED2231S12T is mounted on top of the mother board to drive the SiC module. The configuration of 6ED2231S12T is shown in Figure 13.

Three capacitors C3, C4, and C5 are used as bootstrap capacitors to provide necessary floating supply voltages VBS1, VBS2, and VBS3 respectively. Thanks to the three-bootstrap diode integration in 6ED2231S12T, external bootstrap diodes are not needed.

6ED2231S12T (high voltage integrated circuit) HVIC is equipped with ITRIP input pins. This functionality can be used to detect overcurrent events in the DC bus. When the HVIC detects an overcurrent event through the ITRIP pin, the output is shut down and the RFE is pulled to VSS to report the fault condition. The RFE can also be used as the enable input pin and fault-clear time programmable pin. The fault-clear time setup is based on the datasheet of 6ED2231S12T.

The main feature of 6ED2231S12T designed on Infineon's C5SOI technology is its tolerance towards negative transient voltage in inductive load applications. 6ED2231S12T can tolerate repetitive negative transient voltage of up to 100 V (pulse width up to 700 nanoseconds).

System design

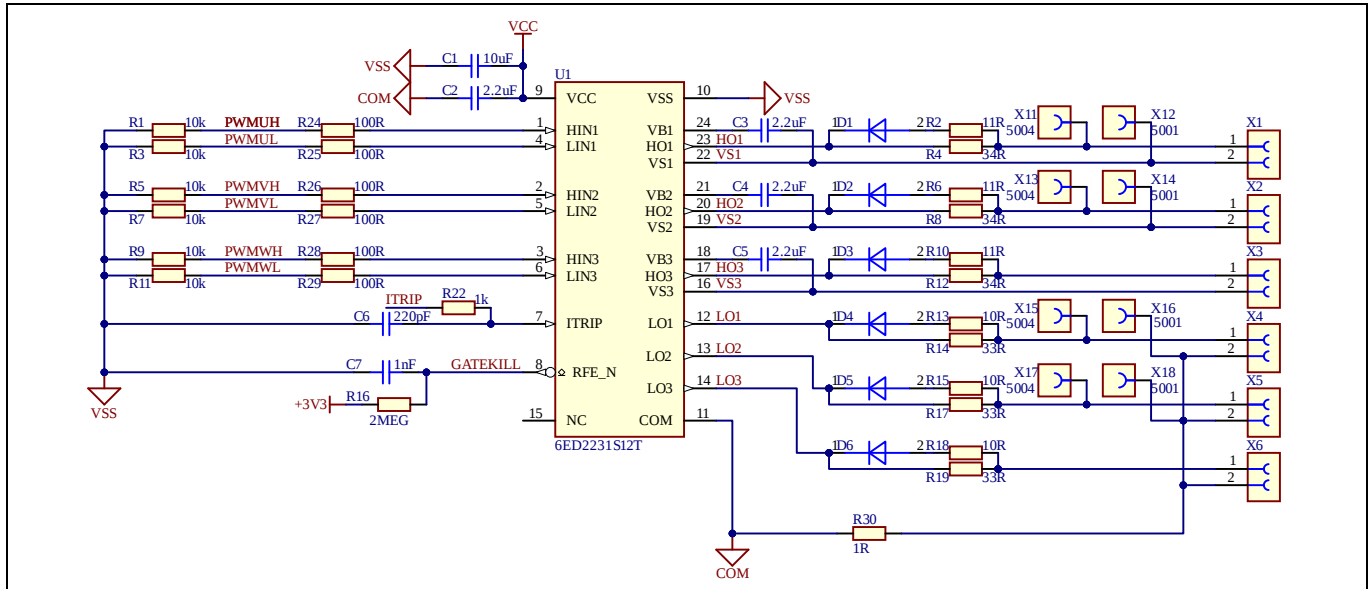


Figure 13 Drive circuit design with 6ED2231S12T

3.1.4 Overcurrent protection

The overcurrent circuit is shown in Figure 12. To save power loss of the shunt resistor, the R_{shunt} value is set as 10 mΩ by using three 30 mΩ / 3 W surface-mount device (SMD) resistors (R15/R16/R17) and low equivalent series inductance (ESL) in parallel. In the design, the target current for overcurrent protection (I_{OCP}) is 25 A. The overcurrent threshold of the ITRIP pin is 0.5 V. An additional 0.25 V DC-bias voltage is needed at the ITRIP pin to meet the target current of 25 A. This is achieved by using resistor dividers R19 and R20 with 3.3 V supply.

The I_{OCP} is calculated using:

$$I_{ocp} = \frac{(V_{ITRIP+} - \frac{R_{19}}{R_{19} + R_{20}} * 3.3V)}{R_{shunt}}$$

$$= 25.2 \text{ A}$$

Here, V_{ITRIP+} is the positive going threshold for ITRIP and its typical value is 0.5 V, $R_{19} = 1 \text{ k}\Omega$, and $R_{20} = 11.3 \text{ k}\Omega$.

3.1.5 NTC thermistor configuration

FS55MR12W1M1H_B11 includes a NTC thermistor. Its temperature curve is shown in Figure 14. The resistance of the NTC thermistor is 5 kΩ at 25°C and 493 Ω at 100°C.

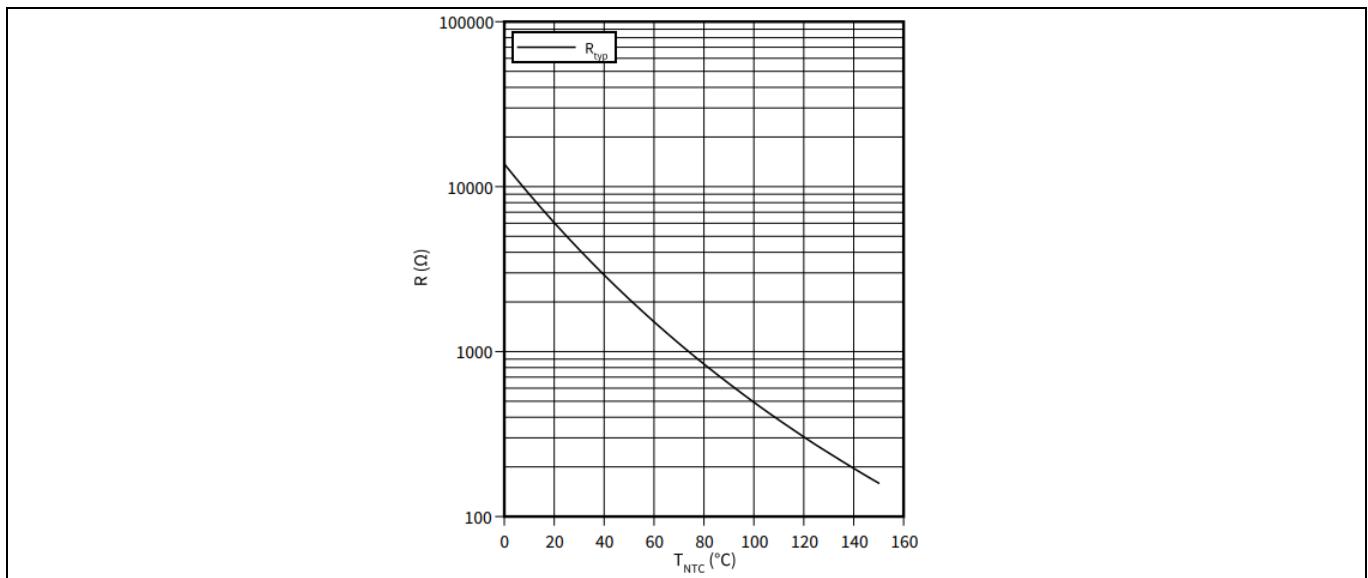


Figure 14 Typical temperature characteristic of the NTC thermistor

A 1 kΩ pull-up resistor is already located on the daughter board. As shown in the NTC thermistor configuration in Figure 15, the sensing voltage V_{TH} equals 2.75 V at 25°C and 1.09 V at 100°C. In the MCEWizard, the overtemperature voltage threshold of the NTC thermistor is set to 1.09 V to protect the SiC module.

Note: If EVAL-M1-101T is used as the control board, the 4.87 kΩ pull-up resistor for NTC needs to be removed to avoid conflict with the pull-up resistor on the daughter board.

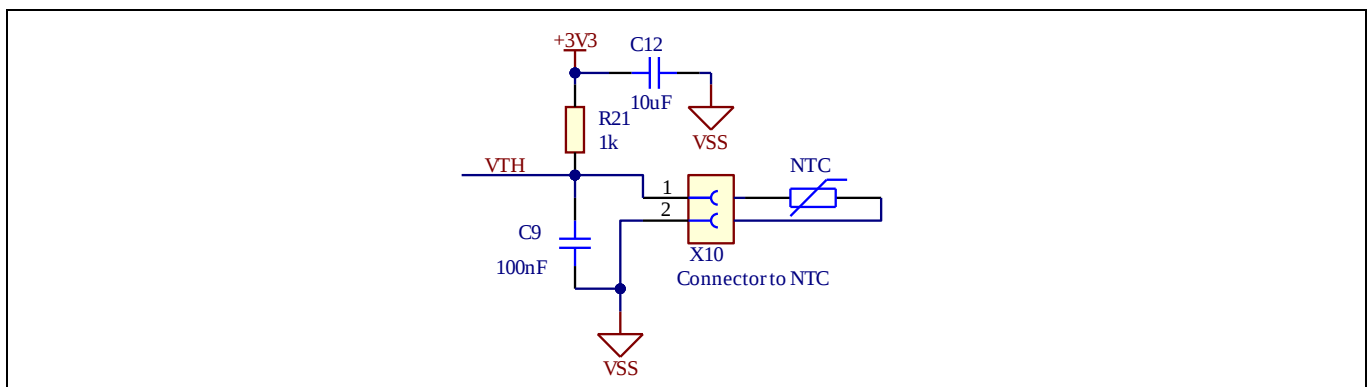


Figure 15 NTC thermistor configuration

3.1.6 Auxiliary power supply

The auxiliary power supply circuit adopts the quasi-resonant, fly-back controller ICE5QSAG and the CoolSiC™ 1700 V SiC MOSFET IMBF170R1K0M1 in a TO-263-7 package. There are two secondary windings. One generates 18 V DC and the other generates 7 V DC. The 18 V DC is connected to the gate drivers. 3.3 V power supply is derived from the 7 V DC using the linear regulator IFX25001ME V33. This 3.3 V power supply is used in the overcurrent bias circuit. Both 18 V and 3.3 V are also present at the 20-pin interface connector X8 on the daughter board. The primary ground, and secondary +18 V and +3.3 V reference grounds are in a star ground connection on the main board as shown in the schematic in Figure 18.

System design

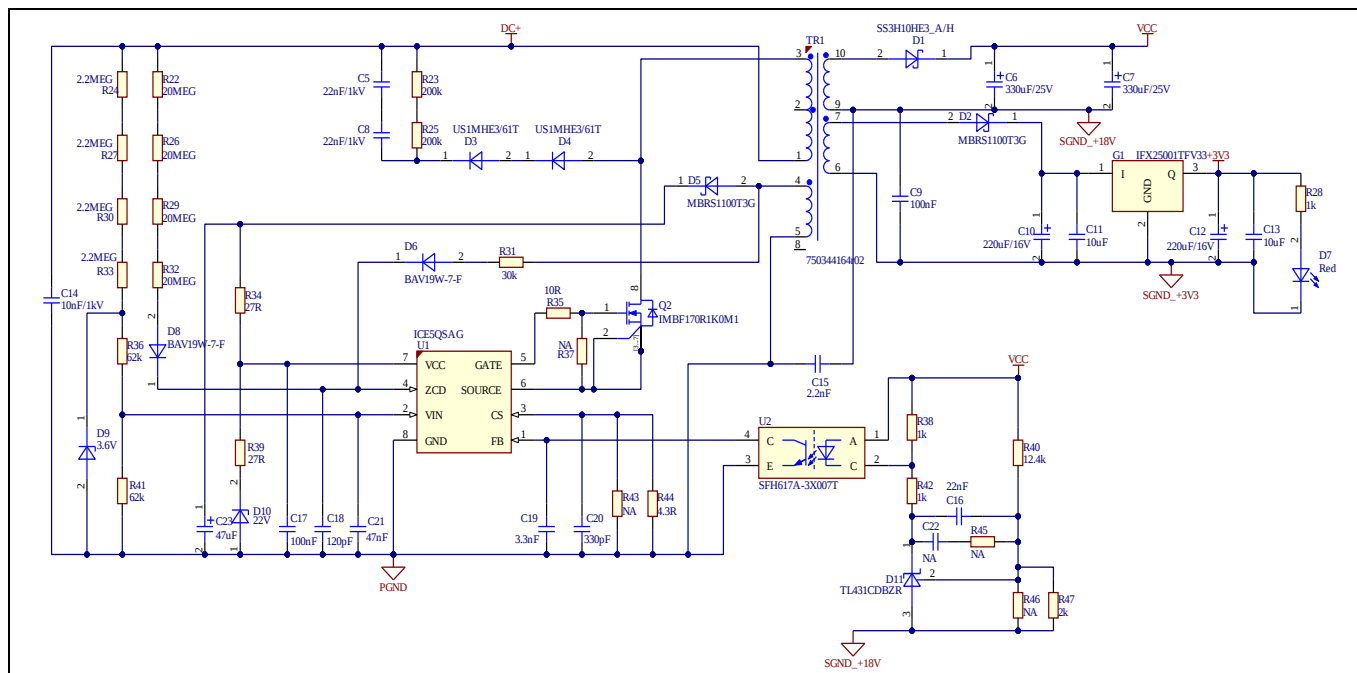


Figure 18 Auxiliary power supply circuitry

3.3 Layout

3.3.1 Layout details

Detailed layouts of the power inverter board and daughter board are shown in Figure 19 to Figure 22.

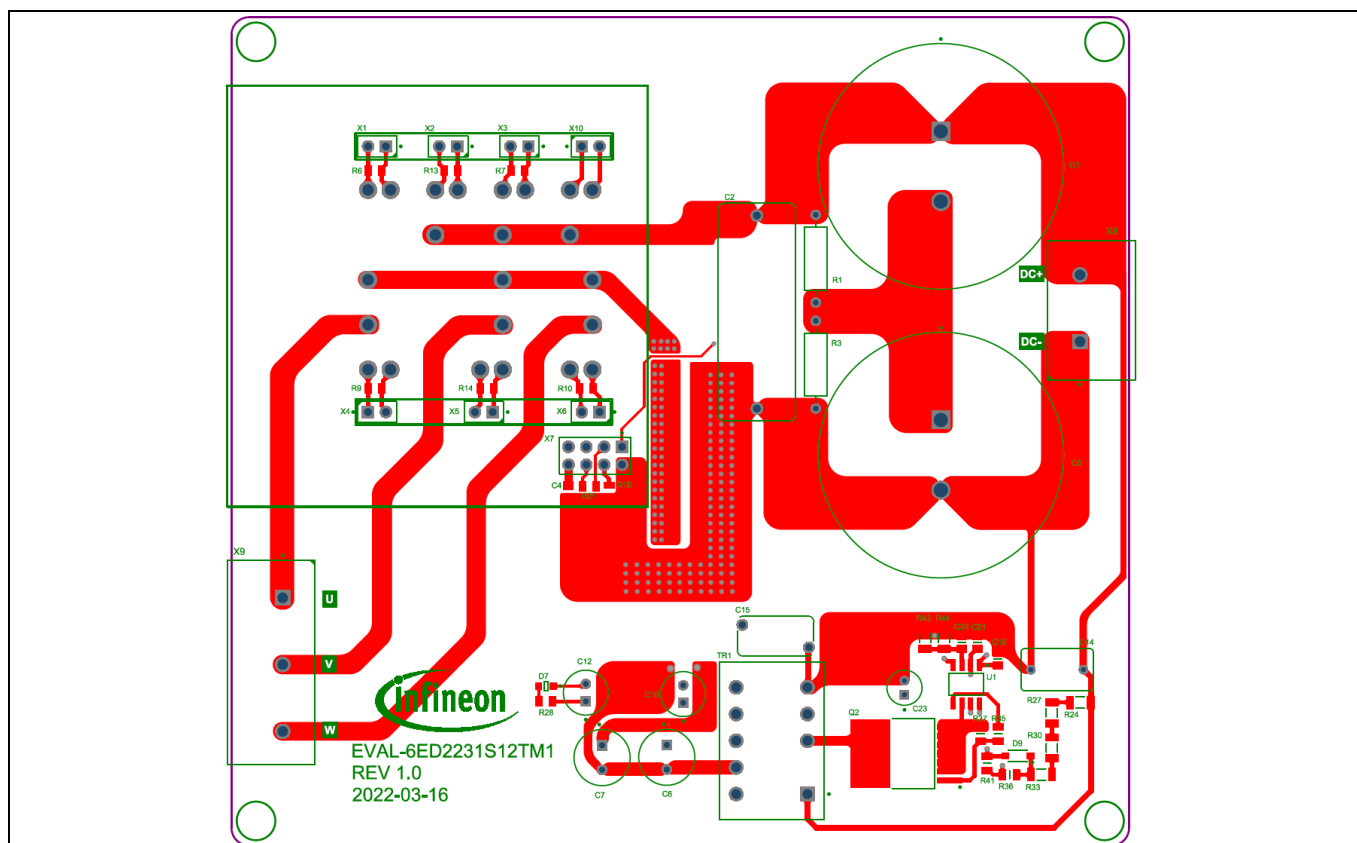


Figure 19 Power inverter board layout (top view)

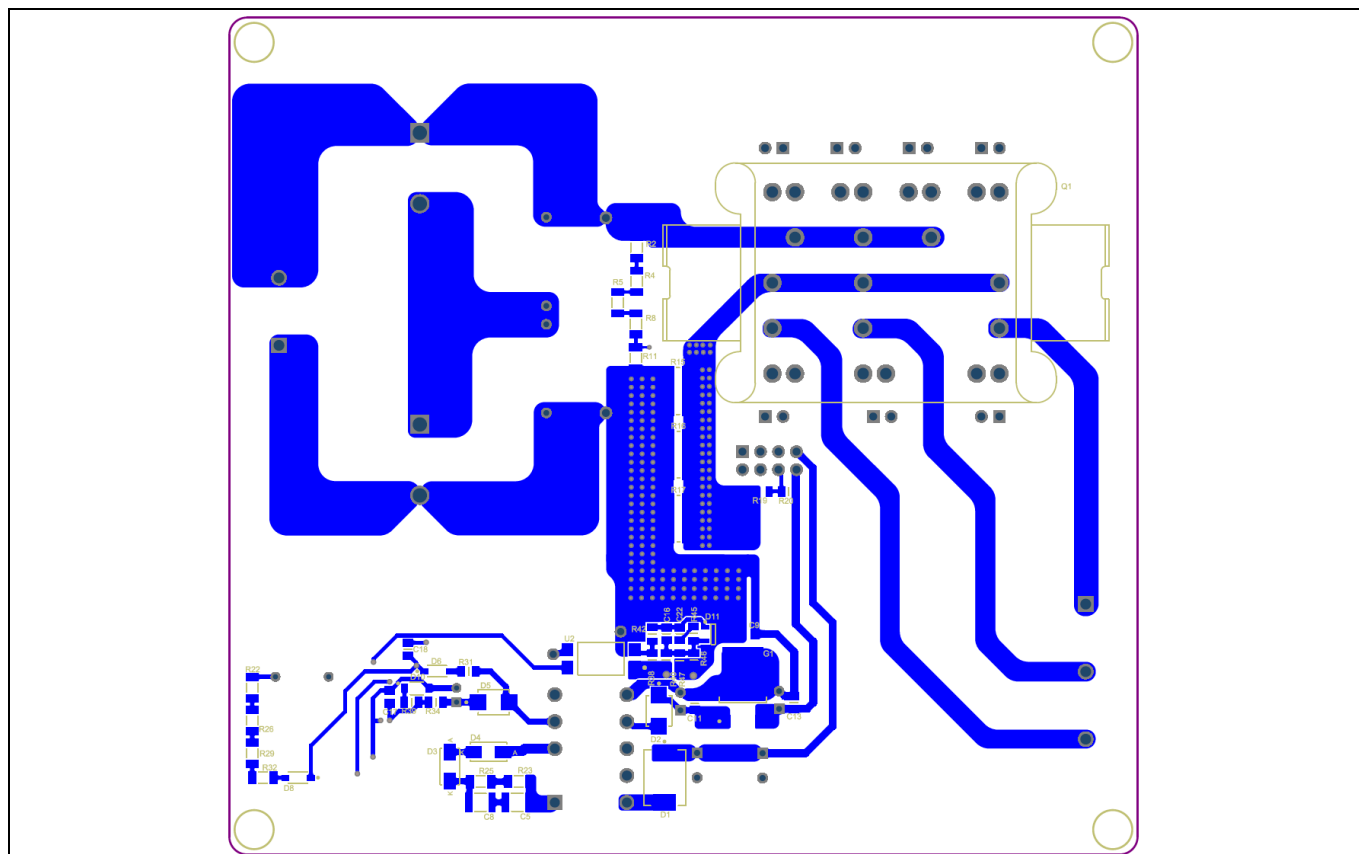


Figure 20 Power inverter board layout (bottom view)

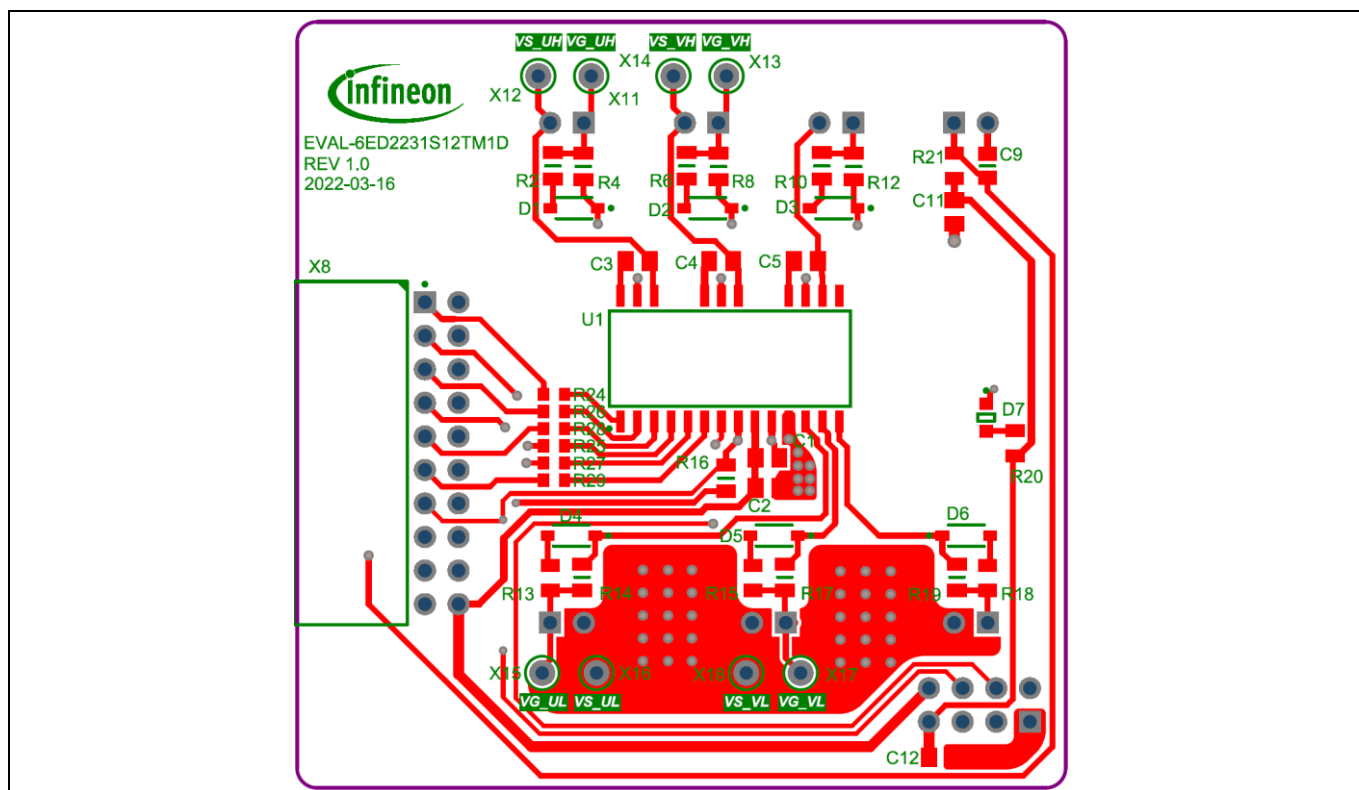


Figure 21 Drive circuitry layout of the daughter board (top view)

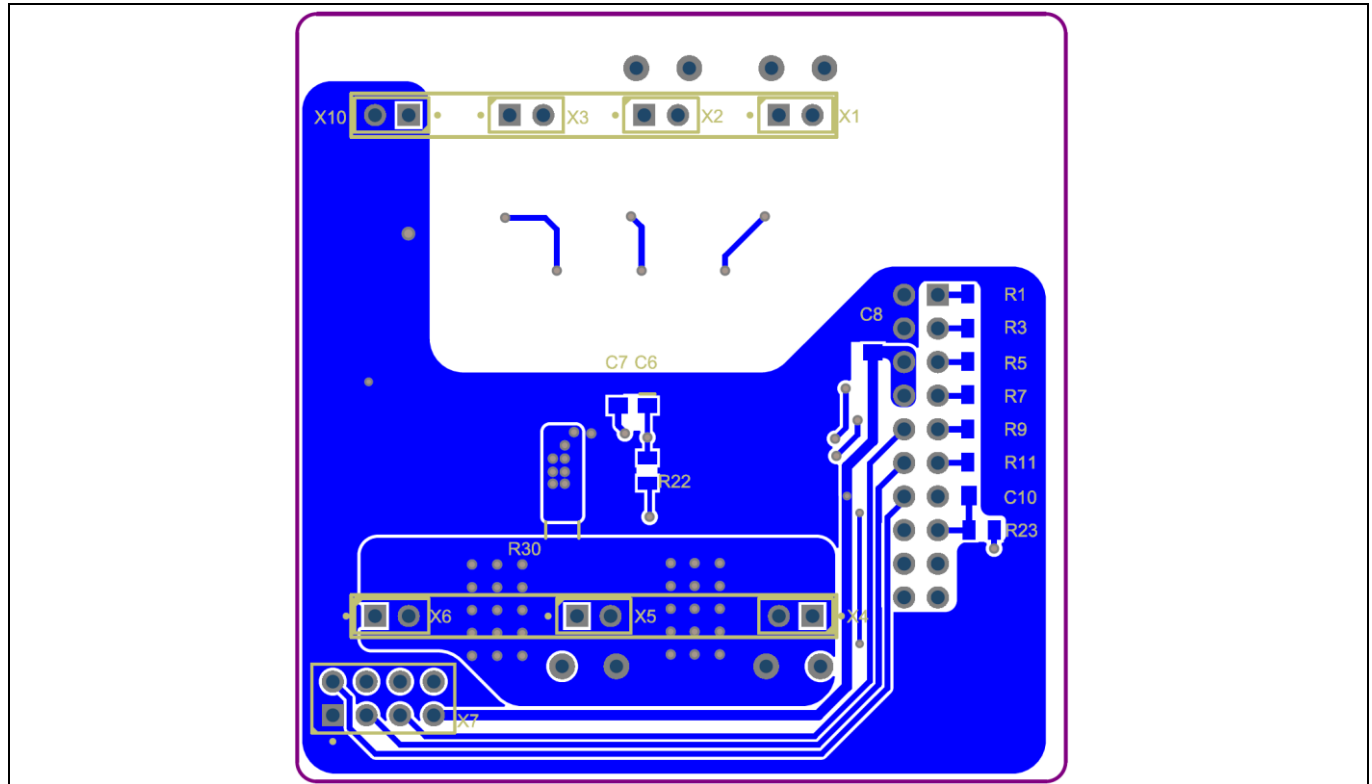


Figure 22 Drive circuitry layout of the daughter board (bottom view)

3.3.2 Layout guidelines

Some basic layout guidelines are as follows:

- The V_{CC} and V_{BS} bypass capacitors should be close to the IC
- The drive loop should be as small as possible
- The loop of VSS and COM should be made as small as possible by connecting the VSS and COM directly at the shunt-resistor terminals
- The two current-sensing traces should be started from the shunt terminals and placed close to each other

System design

3.4 Bill of material

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

Table 5 lists the important components used in EVAL-6ED2231S12TM1.

Table 5 BOM of the most important/critical parts

No.	Ref designator	Description	Manufacturer	Manufacturer P/N
1	U1 (daughter board)	1200 V three-phase gate-driver with over-current-protection	Infineon Technologies	6ED2231S12T
2	Q1 (mother board)	EasyPACK 1B 1200 V six-pack module with CoolSiC MOSFET	Infineon Technologies	FS55MR12W1M1H_B11
3	U1 (mother board)	Quasi-resonant controller	Infineon Technologies	ICE5QSAG
4	Q2 (mother board)	1700 V/1 Ω SiC MOSFET in TO263-7 package	Infineon Technologies	IMBF170R1K0M1
5	G1 (mother board)	5 V/400 mA linear voltage regulator	Infineon Technologies	IFX25001TF V33
6	R15, R16, R17 (mother board)	30 mR / 3 W SMD shunt resistor	Viking	CS25FTG:R030W
7	C1, C3 (mother board)	470 μ F 450 V aluminum electrolytic capacitor	Würth	861011486024
8	C2 (mother board)	0.47 μ F film capacitor - 1000V (1 kV) polyester, metallized radial	Würth	890493427007CS

3.5 Connector details

Table 6 Connectors

PIN	Label	Function
	X1, X2, X3, X4, X5, X6, X7, X10	Daughter and mother board connections
DC+, DC-	X8 (DC+/DC-, mother board)	DC power supply input
U, V, W	X9 (U/V/W)	Three phaseouts (U/V/W) to the motor
	X8 (daughter board)	iMOTION™ MADK-M1 20-pin interface connector

System performance

4 System performance

4.1 System setup for running a BLDC motor

EVAL-6ED2231S12TM1 is tested while running a BLDC motor in the setup shown in Figure 23.

Test conditions:

- Input: $V_{IN} = 510 \text{ VDC}$
- Phaseout current: $I_{PHASE} = 15 \text{ A}_{rms}$
- Room temperature
- BLDC motor: GK6081-6AC31-FE, $I_{PHASE} = 15 \text{ A}$, test at speed = 1450 r/min and 17 Nm
- Heat sink with natural ventilation for the six-pack module

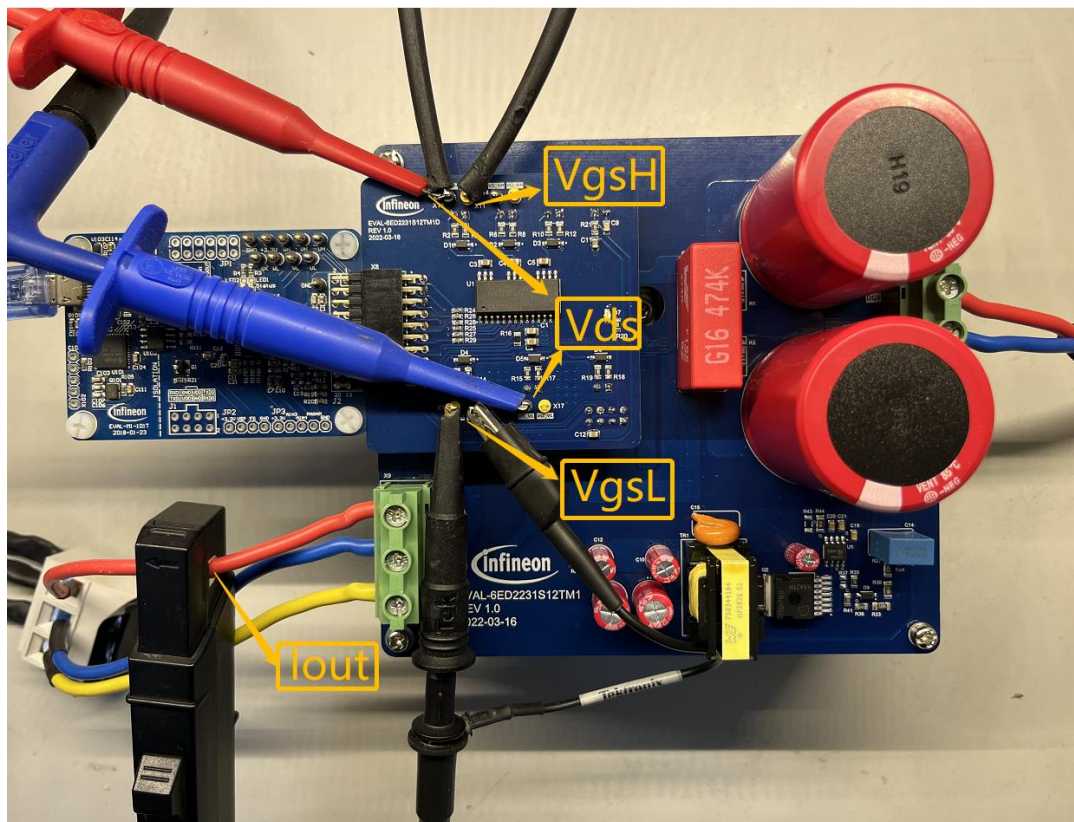


Figure 23 System setup for running a BLDC motor

4.2 The output phase current

Figure 24 shows the waveform when running a BLDC motor.

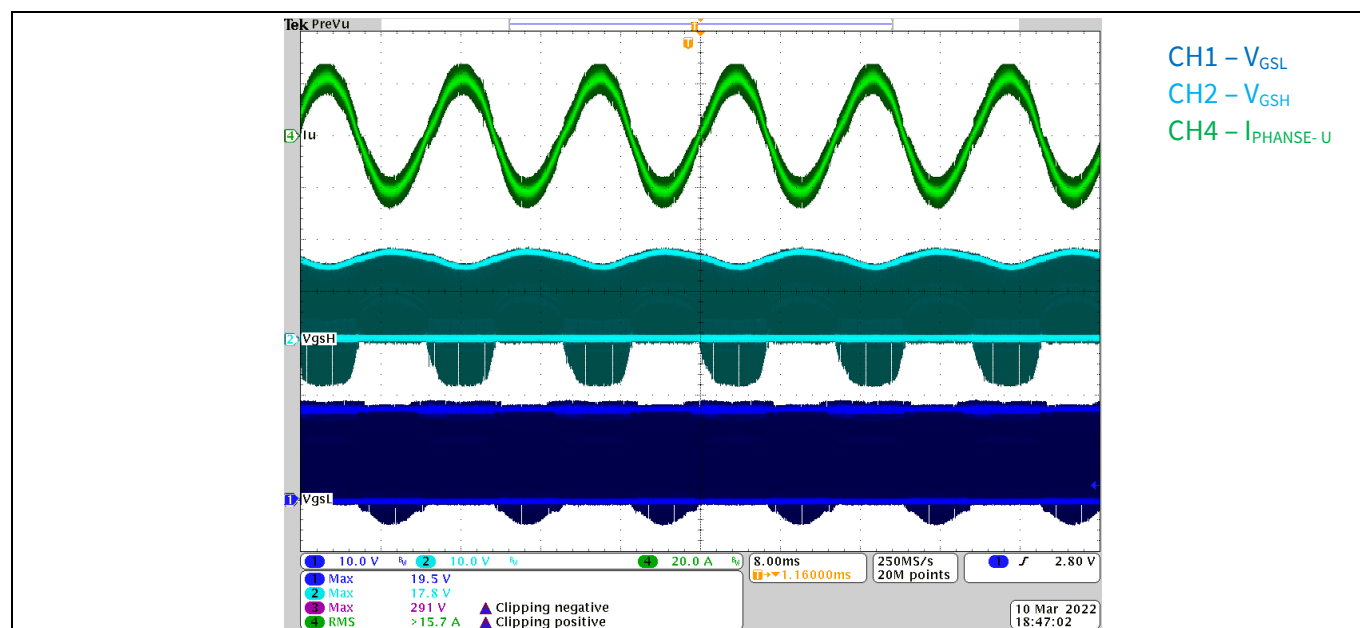


Figure 24 Phase U output current 15.7 A waveform at $V_{IN} = 510$ V, $P_{IN} = 3$ kW, $F_{SW} = 12$ kHz

4.3 Test result for over-current protection

Figure 25 shows the overcurrent detection function of EVAL-6ED2231S12TM1 by ITRIP input of 6ED2231S12T. Overcurrent detection shuts down the outputs of the gate driver if the ITRIP pin input is over 500 mV and lasts longer than 500 nanoseconds. In that case, the overcurrent protection starts when the peak current is around 25.2 A.

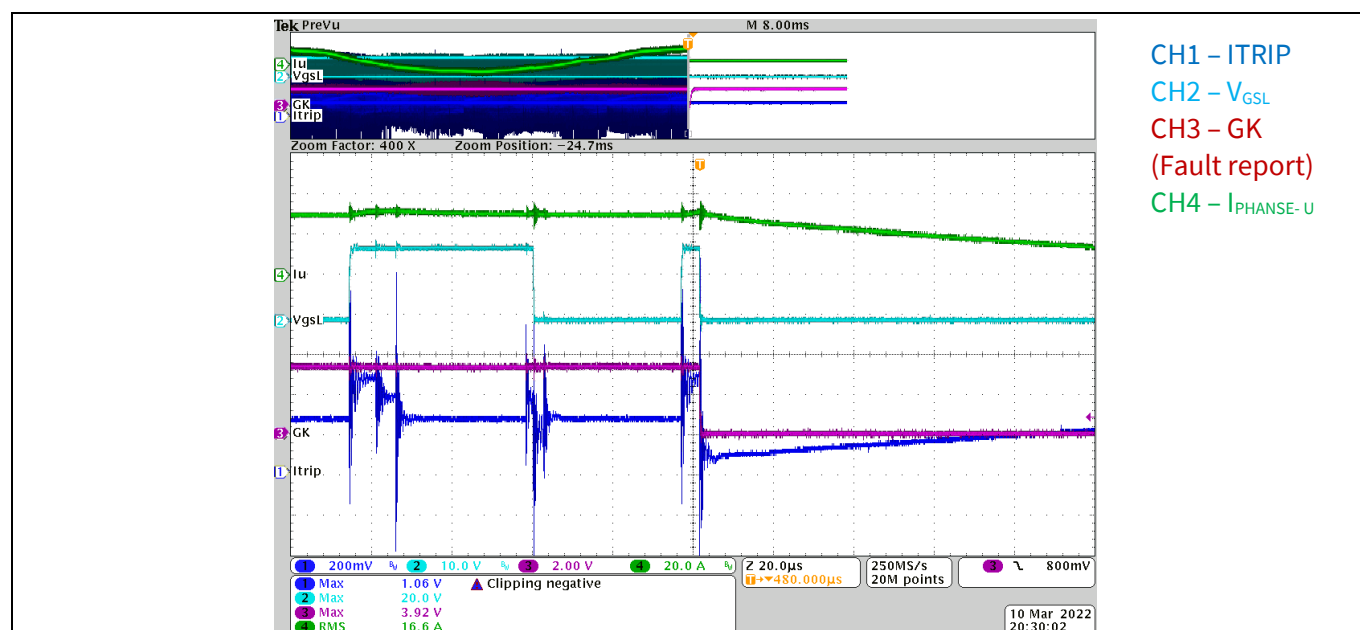


Figure 25 Overcurrent protection

4.4 Test results for short-circuit protection

Figure 26 shows the short-circuit protection of EVAL-6ED2231S12TM1. The total short-circuit protection delay time (including external RC filter, 1 k Ω / 220 pF) is about 1 microsecond when the input voltage V_{IN} is 600 V and the maximum current is about 143 A.

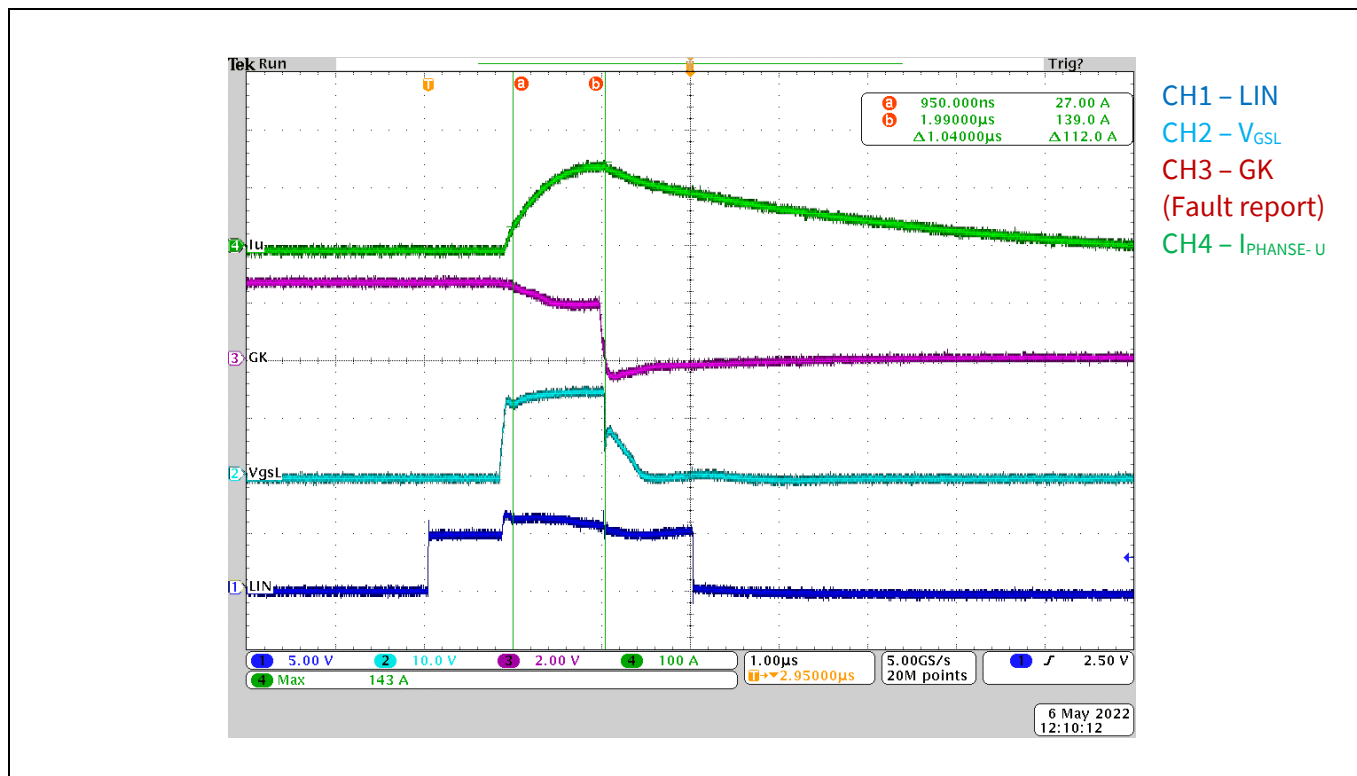


Figure 26 Short-circuit protection at $V_{IN} = 600$ V

4.5 Inverter's efficiency vs input power

Figure 27 shows the inverter's efficiency vs different input powers at $V_{IN} = 510$ V, $I_{PHASE} = 11.2$ A, $F_{SW} = 16$ kHz, and $T_a = 25^\circ\text{C}$.

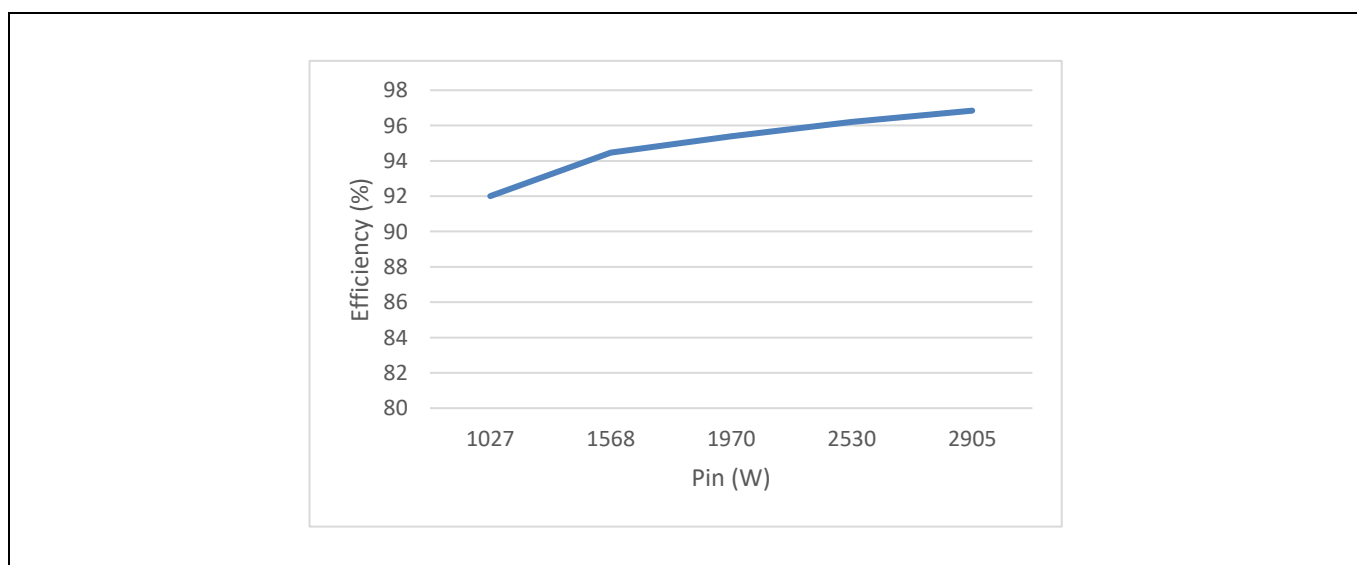


Figure 27 Inverter's efficiency vs input power at $V_{IN} = 510$ V, $I_{PHASE} = 11.2$ A, $F_{SW} = 16$ kHz, $T_a = 25^\circ\text{C}$

System performance

4.6 Inverter's efficiency vs carrier frequency

Figure 28 shows the inverter efficiency vs different carrier frequencies at $V_{IN} = 510\text{ V}$, $I_{PHASE} = 11.2\text{ A}$, $P_{IN} = 2\text{ kW}$, and $T_a = 25^\circ\text{C}$.

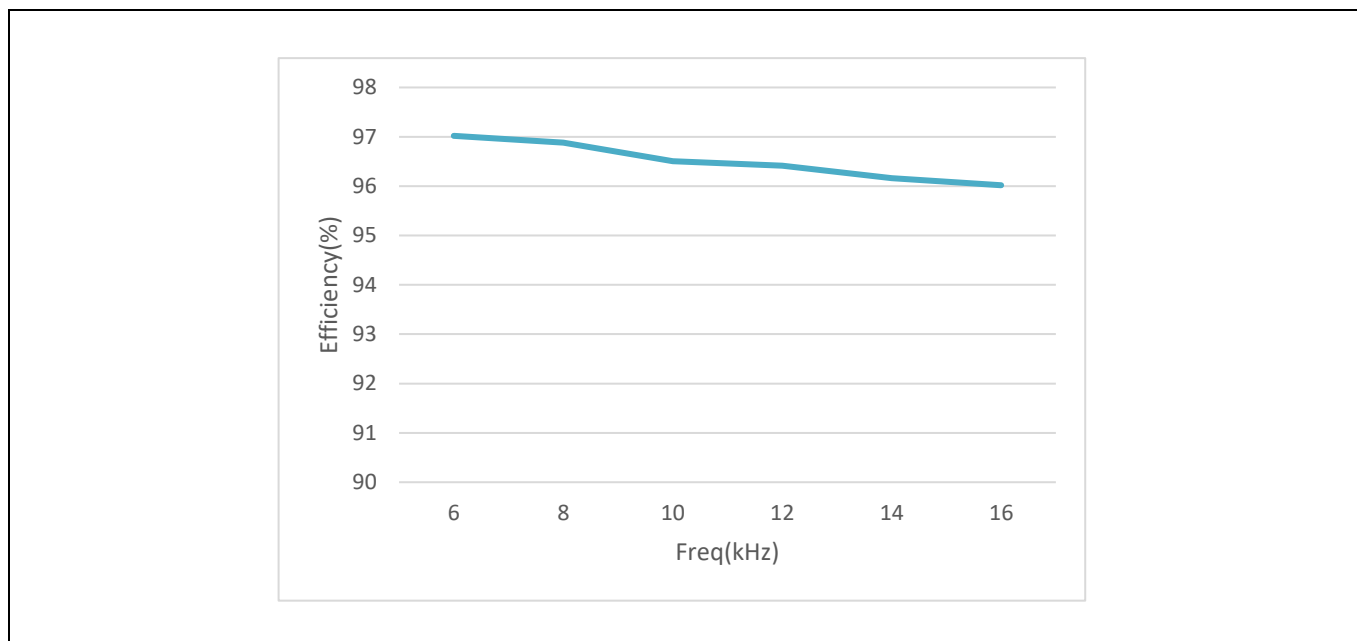


Figure 28 Inverter efficiency vs carrier frequency at $V_{IN} = 510\text{ V}$, $I_{PHASE} = 11.2\text{ A}$, $P_{IN} = 2\text{ kW}$, $T_a = 25^\circ\text{C}$

5 References and appendices

5.1 Abbreviations and definitions

Table 7 **Abbreviations**

Abbreviation	Meaning
IC	Integrated circuit
IGBT	Insulated gate bipolar transistor
DC	Direct current
AC	Alternating current
BLDC	Brushless direct current
SiC	Silicon carbide
PWM	Pulse width modulation
NTC	Negative temperature coefficient
EVAL	Evaluation board
PCB	Printed circuit board
SOI	Silicon on insulator

5.2 References

- [1] Infineon Technologies AG. Datasheet of 6ED2231S12T (2022) V1.0 [6ED2231S12T - Infineon Technologies](#)
- [2] Infineon Technologies AG. Datasheet of FS55MR12W1M1H_B11 (2021) V0.10 [FS55MR12W1M1H_B11 - Infineon Technologies](#)
- [3] Infineon Technologies AG. Datasheet of ICE5QSAG (2020) V2.1 [ICE5QSAG Infineon Technologies](#)
- [4] Infineon Technologies AG. Datasheet of IMBF170R1K0M1 (2021) V2.3 [IMBF170R1K0M1 Infineon Technologies](#)
- [5] Infineon Technologies AG. Datasheet of IFX25001TF V33 (2019) V1.10 [IFX25001TF V33 Infineon Technologies](#)
- [6] Infineon Technologies AG. User manual of EVAL-M1-101T (2018) V1.6 [EVAL-M1-101T - Infineon Technologies](#)
- [7] Infineon Technologies AG. Application note: Managing transients in control IC driven power stages (2017) V1.0 [Managing Transients in Control IC Driven Power Stages \(infineon.com\)](#)
- [8] Infineon Technologies AG. iMOTION™ - MCE - Software Reference Manual (2020) v1.3 [iMOTION™ Motion Control Engine \(infineon.com\)](#)

Revision history

Revision history

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