EVAL-M1-IR2214 User Guide

1200 V junction-isolation gate driver IR2214SS evaluation board

About this document

Scope and purpose

This user guide provides an overview of the evaluation board EVAL-M1-IR2214 including its main features, key components and design details. The user guide describes how to run a brushless direct current (BLDC) motor with the evaluation board, and verifies the board by a double-pulse test for a higher power rating.

Intended audience

This document is intended for all technical specialists who have a knowledge of motor control and high-power electronics converters. The board should be used under laboratory conditions.

Evaluation board

The board EVAL-M1-IR2214 is designed to evaluate the 1200 V junction-isolation gate driver IR2214SS along with the 1200 V/50 A EconoPIM™3 module FP50R12KT4G.

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-M1-IR2214	MADK EVAL	Boxed	1	EVALM1IR2214TOBO1
IR2214SS	SSOP24	Tape & Reel	2000	IR2214SSTRPBF
EVAL-M1-101T	MADK EVAL	Container	1	EVALM1101TTOBO2
FP50R12KT4G	AG-ECONO3	Tray	10	FP50R12KT4GBOSA1
ICE5QSAG	PG-DSO-8	Tape & Reel	2500	ICE5QSAGXUMA1
IMBF170R1K0M1	PG-TO263-7	Tape & Reel	1000	IMBF170R1K0M1XTMA1
IFX25001TF V50	PG-TO252-3	Tape & Reel	2500	IFX25001TFV50ATMA1

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Safety precautions

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

Table 1 **Safety precautions**

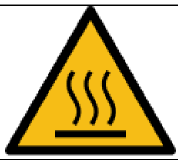
	**Warning:** *The DC link potential of this board is up to 800 VDC. When measuring voltage waveforms by oscilloscope, high voltage differential probes must be used. Failure to do so may result in personal injury or death.*
	**Warning**: *The evaluation or reference board contains DC bus capacitors which 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.*

Table of contents

1 The board at a glance

The evaluation board EVAL-M1-IR2214 contains the gate driver ICs IR2214SS, the EconoPIM™3 module FP50R12KT4G, the bus capacitors and peripheral circuits.

1.1 Delivery content

The complete board EVAL-M1-IR2214 is delivered with daughter board for auxiliary power supplies included.

1.2 Block diagram

Figure 1 shows a typical application diagram of the EVAL-M1-IR2214 for driving a BLDC motor. All the power circuits are included in the EVAL-M1-IR2214. The rectifier, brake and inverter are combined in the power integration module (PIM) FP50R12KT4G. The daughter board provides the power supplies for both gate drivers and controller board.

The system adopts the single-shunt configuration, which is prevalent for current BLDC motor drive applications.

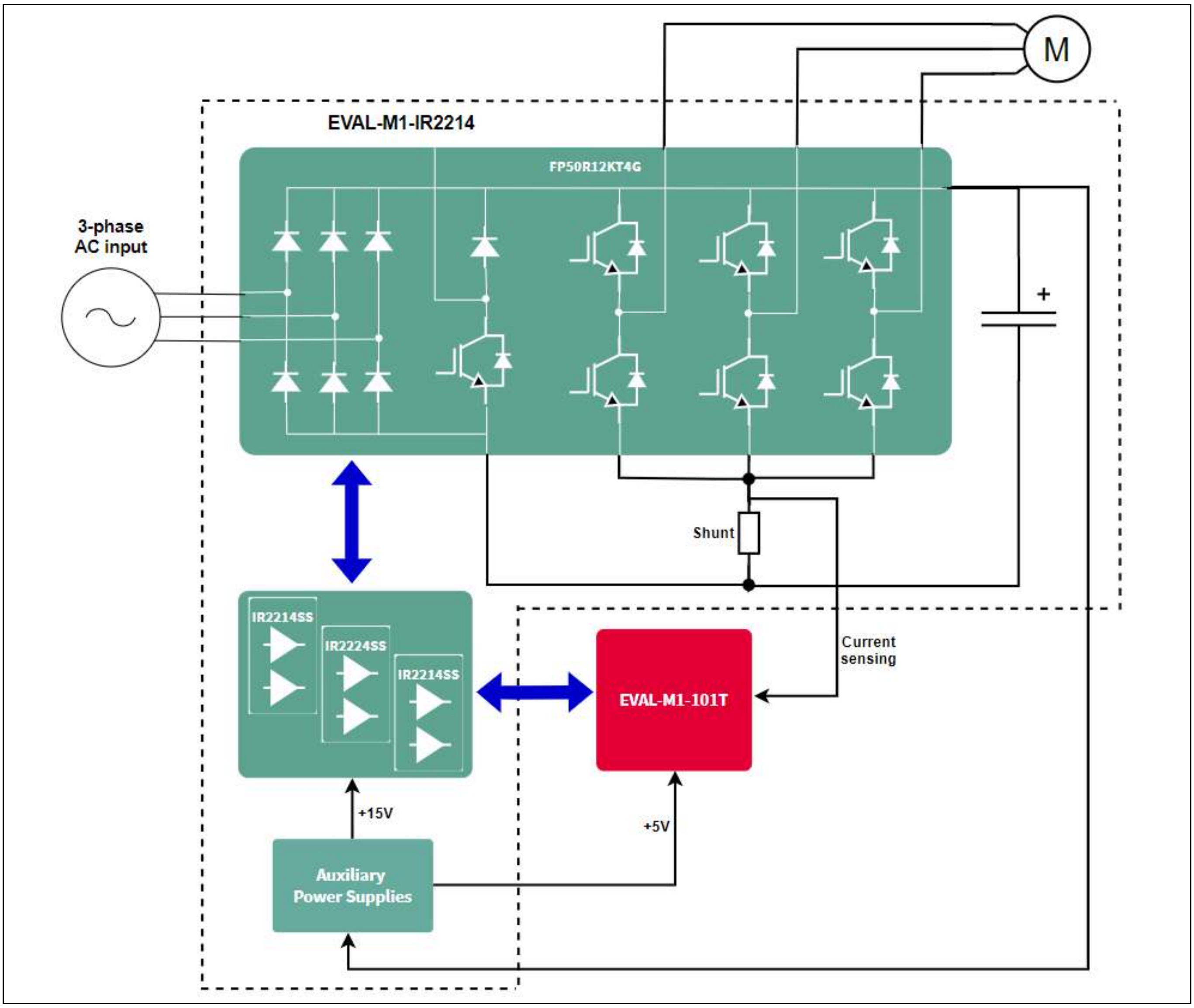
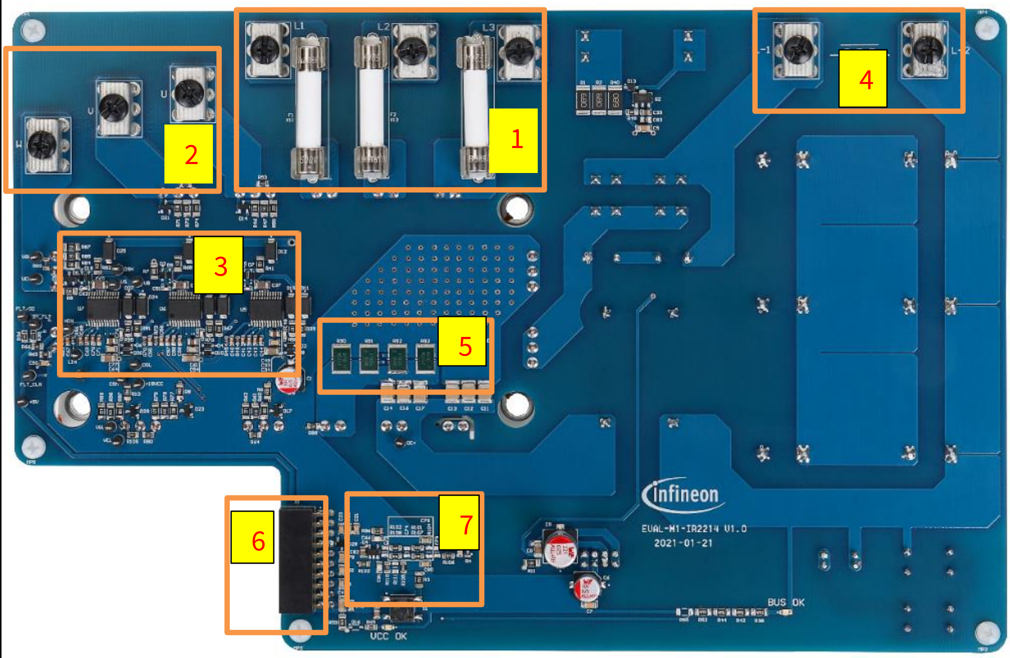


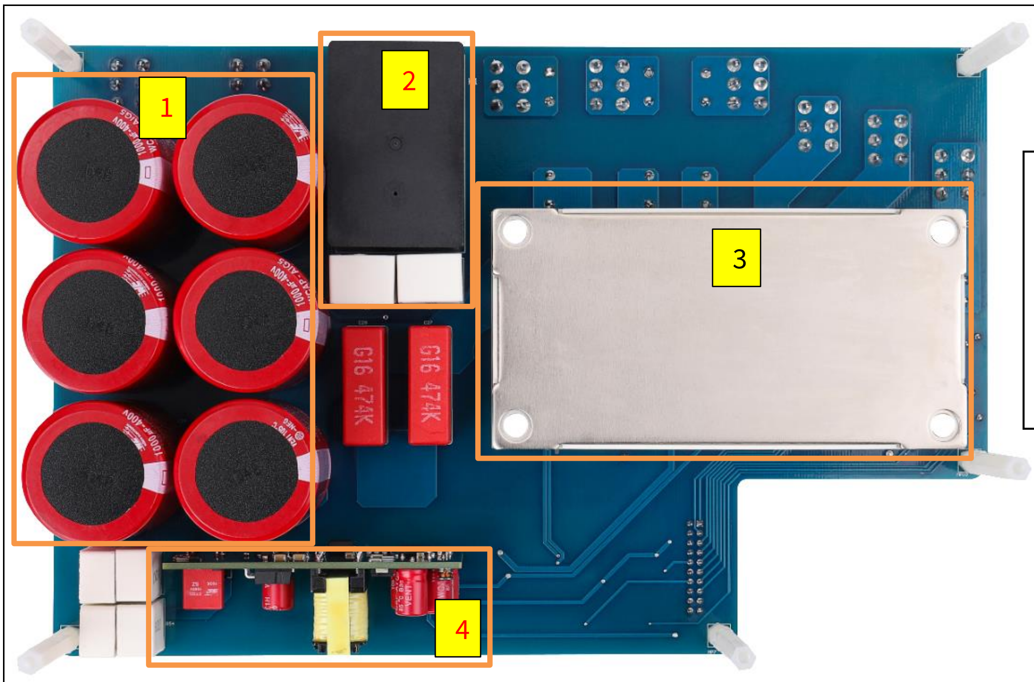
Figure 1 Typical application block diagram of the EVAL-M1-IR2214

The functional blocks of the EVAL-M1-IR2214 are presented in Figure 2 and Figure 3.



1. L1/L2/L3 input with fuses
2. U/V/W phase-out
3. IR2214SS gate drivers
4. External inductor connectors
5. Single shunt
6. iMOTION™ 2.0 M1 interface
7. Current sensing circuit

Figure 2 Functional blocks of the EVAL-M1-IR2214 – top view



1. Bus electrolytic capacitors
2. Relay
3. PIM FP50R12KT4G
4. Daughter board for auxiliary power supply

Figure 3 Functional blocks of the EVAL-M1-IR2214 – bottom view

1.3 Main features

Main features of the EVAL-M1-IR2214 include:

- 380 V_{AC} three-phase input with fuses on the board providing basic electrical protection
- Inrush current limit circuit included for a safer power-on

- Compact design with the EconoPIM™3 FP50R12KT4G which combines the rectifier, brake and inverter in one package
- Optimized system performance with the IR2214SS which includes enhanced features, such as desaturation protection, soft overcurrent shutdown, two-stage turn-on output, separate sink/source output, etc.
- +15 V and +5 V auxiliary power supplies on the board
- M1 interface compatible with the iMOTION™ controller board

1.4 Board parameters and technical data

The key specifications of the EVAL-M1-IR2214 are listed in Table 2.

Table 2 EVAL-M1-IR2214 board specification

Parameter	Symbol	Conditions	Value			Unit
			min	nom	max	
Input						
Input voltage	V_{IN}	Line voltage, three-phase input			480	V_{AC}
Input current	I_{IN}	Phase current			15	A
Output						
Output current	I_{OUT}	RMS phase-out current			23	A
Output power	P_{OUT}	With adequate cooling method			10	kW
Over-current protection		Peak phase-out current defined in MCEWizard			50	A
Thermal protection						
NTC over-temperature threshold	VTH	Configuration in MCEWizard	1.84	4.14		V
			100	25		°C
Switching frequency						
Inverter frequency	F_{SW}			8		kHz
Auxiliary power supply						
Gate driver power supply	VCC			15		V
Controller power supply				5		V
System environment						
Ambient temperature		With adequate cooling method		25		°C
PCB characteristics						
Dimensions		Length		245		mm
		Width		160		mm
		Height		65		mm
Layer				2		
PCB thickness				2		mm
Copper thickness				2		oz.
Weight		Weight of the entire PCB assembly		1240		g
Material		FR-4, RoHS-compliant				

2 System and functional description

2.1 Commissioning

2.1.1 Running a BLDC motor

By connecting the iMOTION™2.0 controller board EVAL-M1-101T through an M1 interface, the power board EVAL-M1-IR2214 can run a BLDC motor. The system connection is shown in Figure 4, and the test results are recorded in section 4.1.

Caution: The required, adequate cooling method should be used to prevent the PIM from overheating, since it is not provided in the scope of delivery.

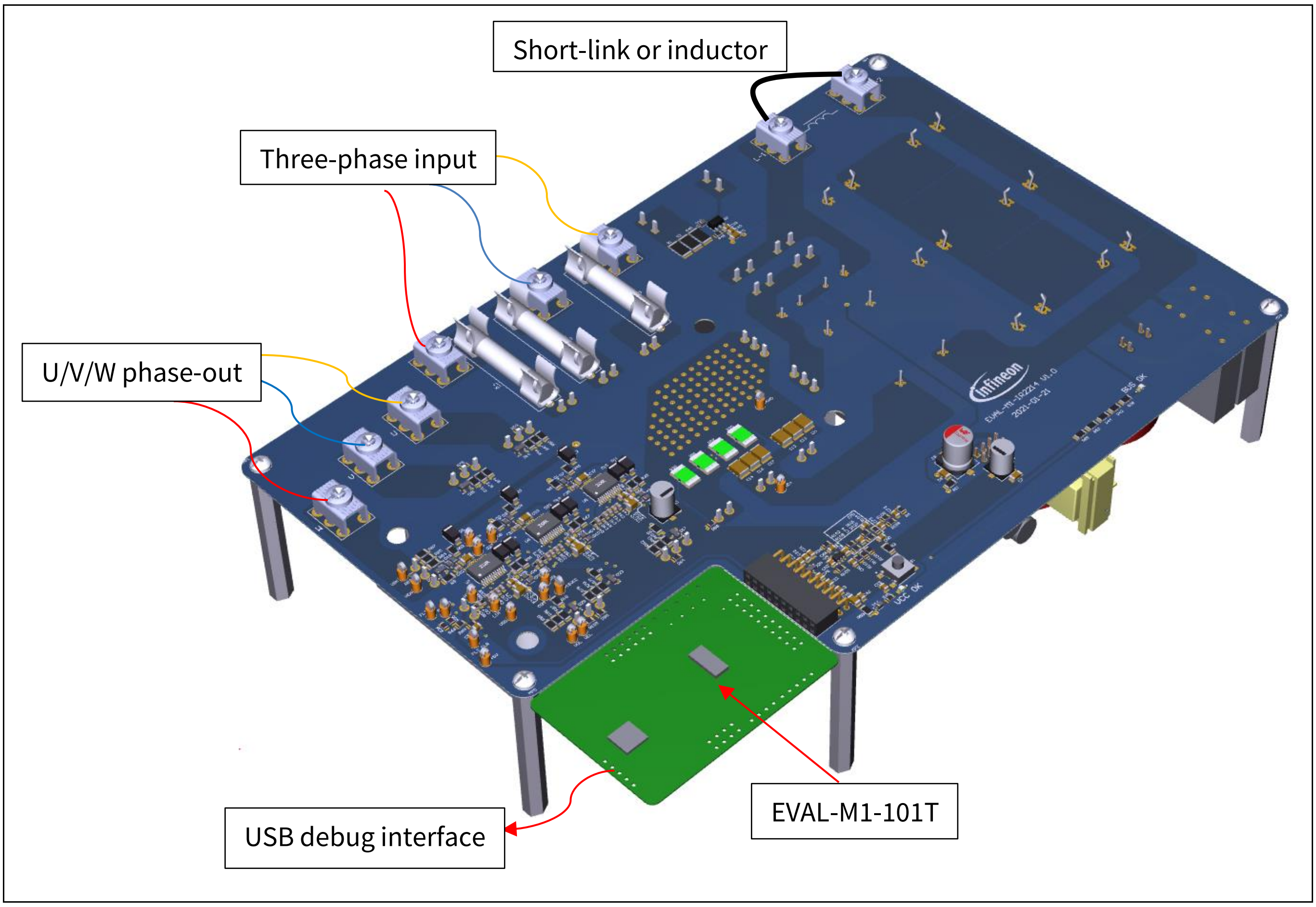


Figure 4 The system connection for running a BLDC motor

2.1.2 Double-pulse test

The double-pulse test is applied to check the robustness of the gate driver IR2214SS under extreme working conditions. Some critical data such as negative V_S and VSS transient should be checked whether they are still within the specification. The worst condition occurs when the double-pulse test is performed on the high-side switch. The test method is illustrated in Figure 5.

Note: The cooling method is not needed for double-pulse test.

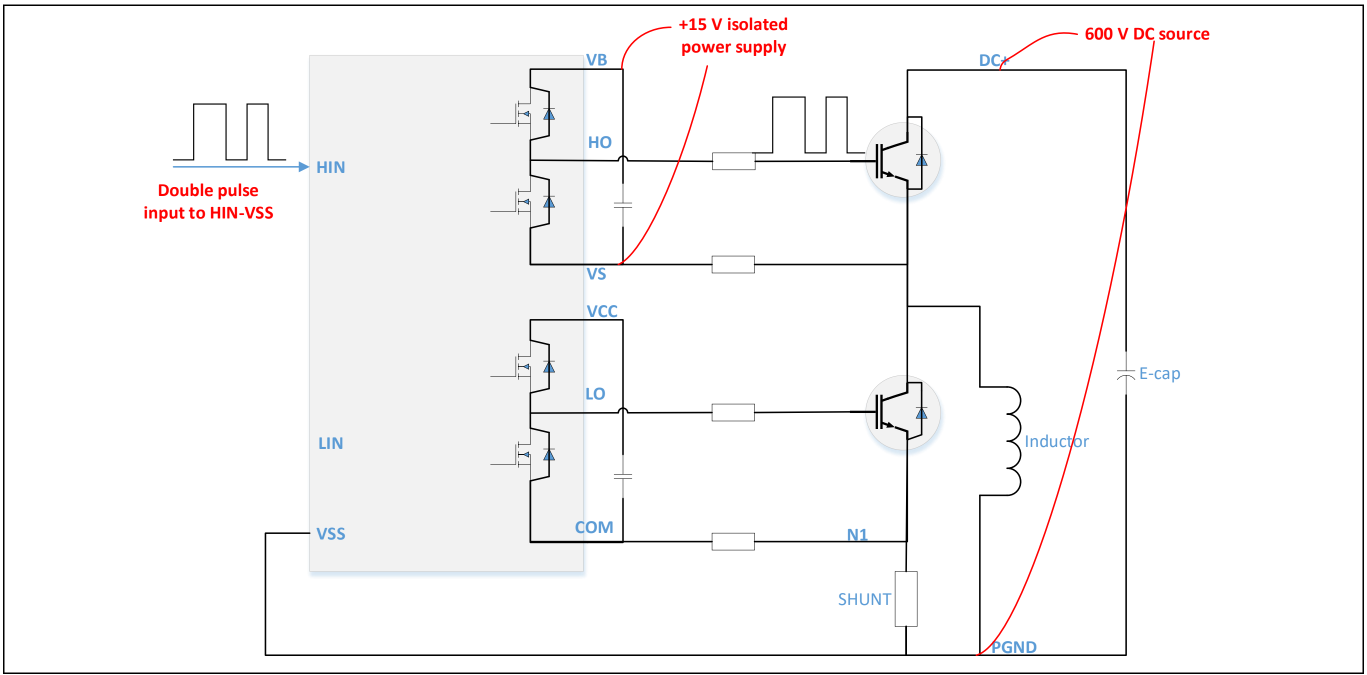


Figure 5 Double-pulse test on the high-side switch

A DC source is used to charge the bus electrolytic capacitors. The positive output of the DC source is connected to the 'DC+' test point, whereas the negative output to the power ground 'PGND' test point on the EVAL-M1-IR2214 board. The double-pulse test is taken on the W-phase since it has the largest ground loop. The test setup is shown in Figure 6, and the test results including the minus V_S are offered in section 0.

Caution: 1. Check the connections according to the right polarities of the DC source.

2. The bus voltage should gradually rise if the DC source has no inrush current limitation.

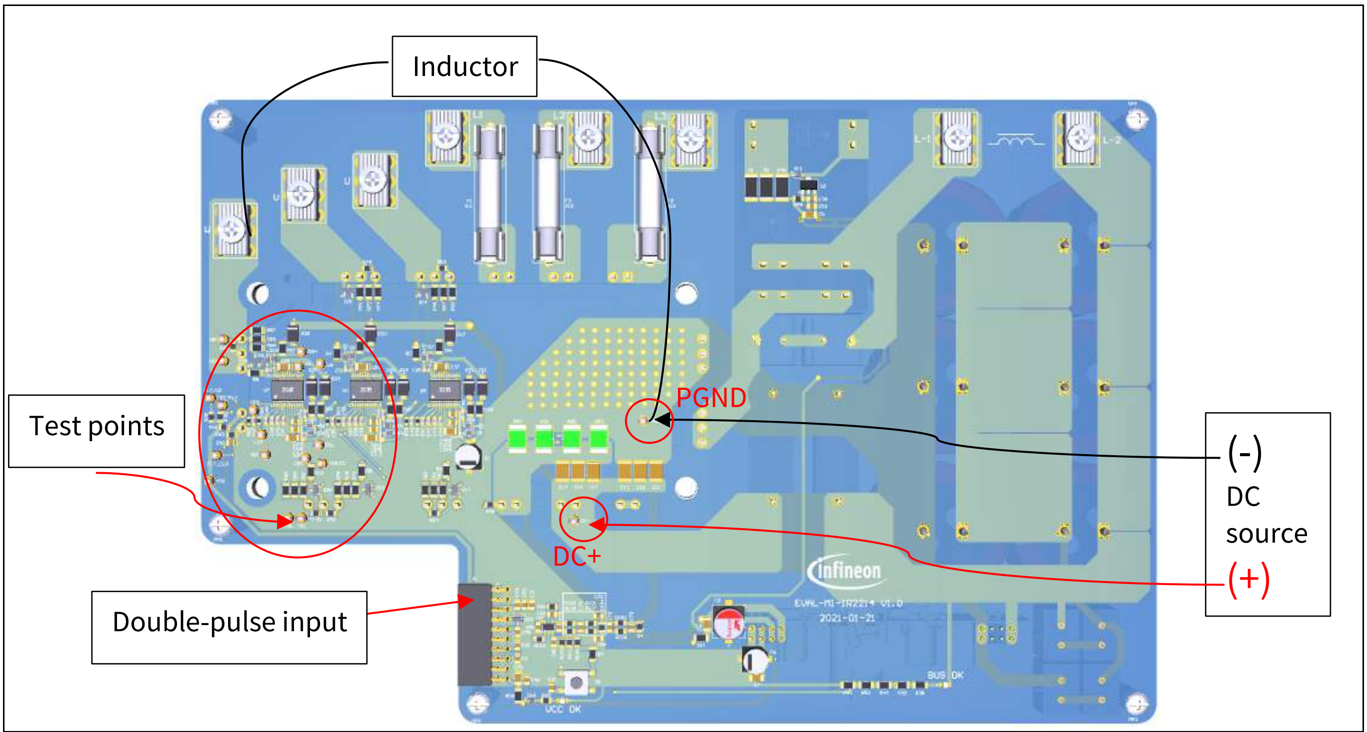


Figure 6 Double-pulse test system setup

2.2 Description of the functional blocks

This chapter covers the hardware design of the EVAL-M1-IR2214 in detail. The users can modify the circuit or re-select the component values based on the actual applications in the field.

2.2.1 Inrush current limitation

To protect input fuses, rectifier and bus capacitors from large inrush current during power-on, the inrush current limitation circuit is usually needed, see Figure 7.

At the beginning of power-on, the relay is open and the bus capacitors are charged through R56 and R57. When the +15 V power supply is established (after around 100 mS), the relay is closed to take over the charge current.

The R1, R2 and R40 are used to regulate the +15 V to +12 V, with which the relay works.

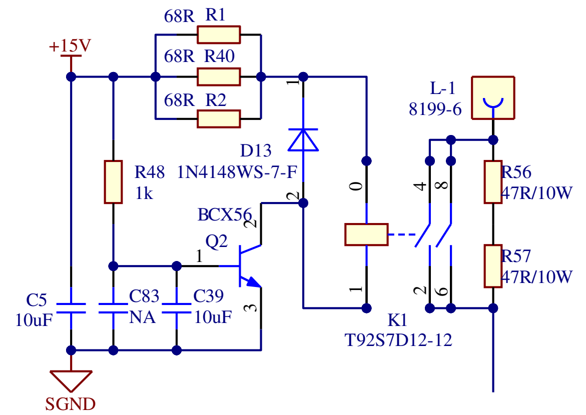


Figure 7 **Inrush current limitation circuit**

2.2.2 DC-link voltage measurement

The bus capacitors should be large enough to stabilize the bus voltage. The resistors R37, R43, R51 and R54 are used for balancing the voltage on the electrolytic capacitors in series, see Figure 8.

Note: The resistor R55 is not soldered on the EVAL-M1-IR2214 main board. There is a 13.3 kΩ pull-down resistor located on the EVAL-M1-101T controller board.

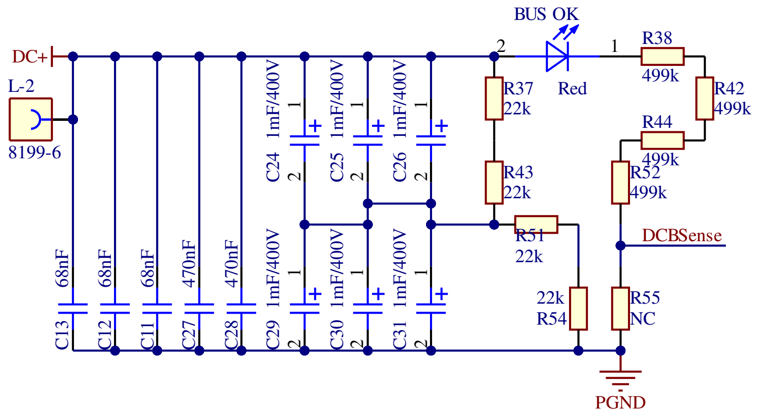


Figure 8 **Bus capacitor configuration and DC bus sensing**

2.2.3 EconoPIM™3 FP50R12KT4G

The EconoPIM™3 FP50R12KT4G combines the three-phase rectifier, brake, inverter and NTC function blocks in one package. The internal structure of the FP50R12KT4G is shown in Figure 9.

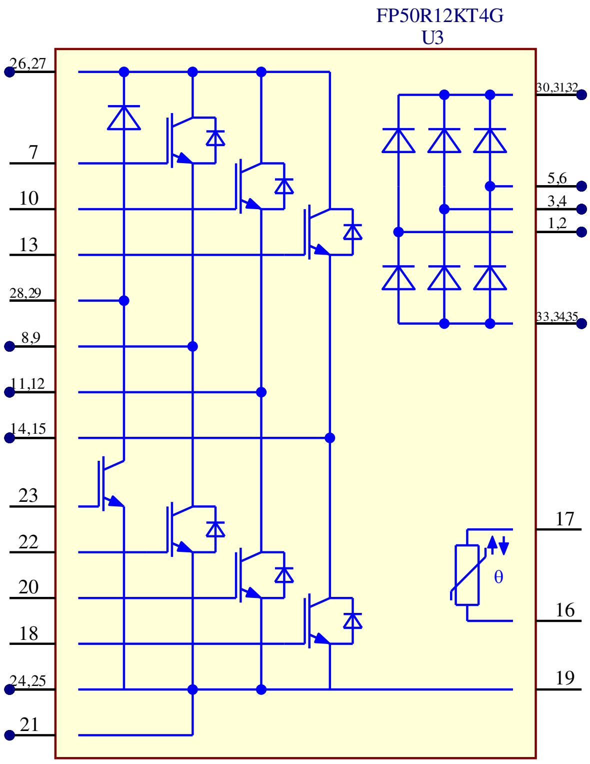


Figure 9 **Internal structure of the FP50R12KT4G**

2.2.4 Drive circuit with the IR2214SS

There are three half-bridge gate drivers IR2214SS used for the inverter drive. The configuration of the IR2214SS is depicted in Figure 10.

The desaturation protection is a key feature of the IR2214SS. The IGBT switching would cause the overshoot/undershoot at the desaturation detection pins DSH/DSL. It is necessary to clamp the DSH/DSL to the power supply VB/+15 VCC and ground reference VS/COM individually, to prevent IC damage. The clamping diodes should have small leakage current at high temperature, like the BAS16J selected herein.

To suppress the voltage spikes between the VSS and COM caused by the IGBT switching, a small resistor R6 is added between the COM and the low-side IGBT emitter N1. The resistor R5 is needed to balance the gate resistance of both the high-side and low-side drive loops.

The FLT_CLR, SY_FLT, FAULT/SD pins of the three IR2214SS ICs are individually connected together. Any fault reported from one IR2214SS will shut down the other two. The MCU can also control the three gate drivers synchronously.

If the desaturation protection is triggered, the $\overline{\text{FAULT/SD}}$ (pin 5) of IR2214SS will be pulled low and the drive outputs are disabled. There should be an active high pulse at the FLT_CLR (pin 3) to clear the fault and release the IC from protection. On this EVAL-M1-IR2214 board, the users have to press the push-button S1 to re-enable the IC.

The diodes D11, D12 and D15 are all 1200 V rated.

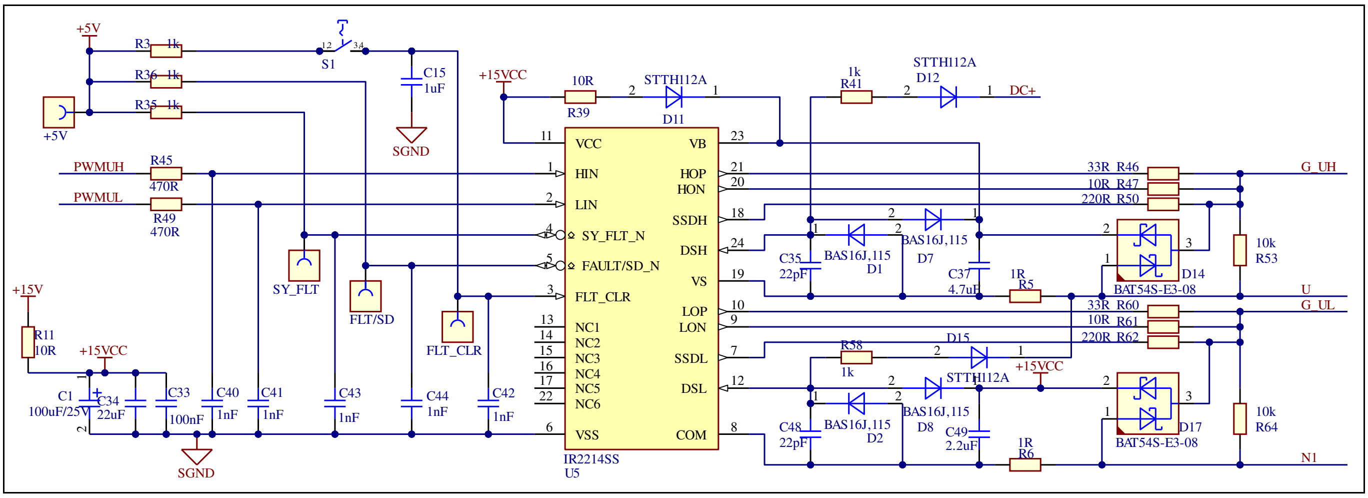


Figure 10 Drive circuit design with the IR2214SS

2.2.5 Current feedback

The current feedback circuit is depicted in Figure 11. The shunt resistor value is 2.5 mΩ by using four 10 mΩ/5 W SMD resistors in parallel.

The current gain is calculated by,

$$IU+=\frac{R110}{R110+R109}*5V+\frac{R96}{R100+R101+R102}*\frac{R104}{R104+R100+R106}*2.5mohm*current$$

$$=2.143+39.6\,mV/A$$

Note: If entering this result to MCEWizard, the resistor R6 on the EVAL -M1-101T board should be removed (without an extra offset).

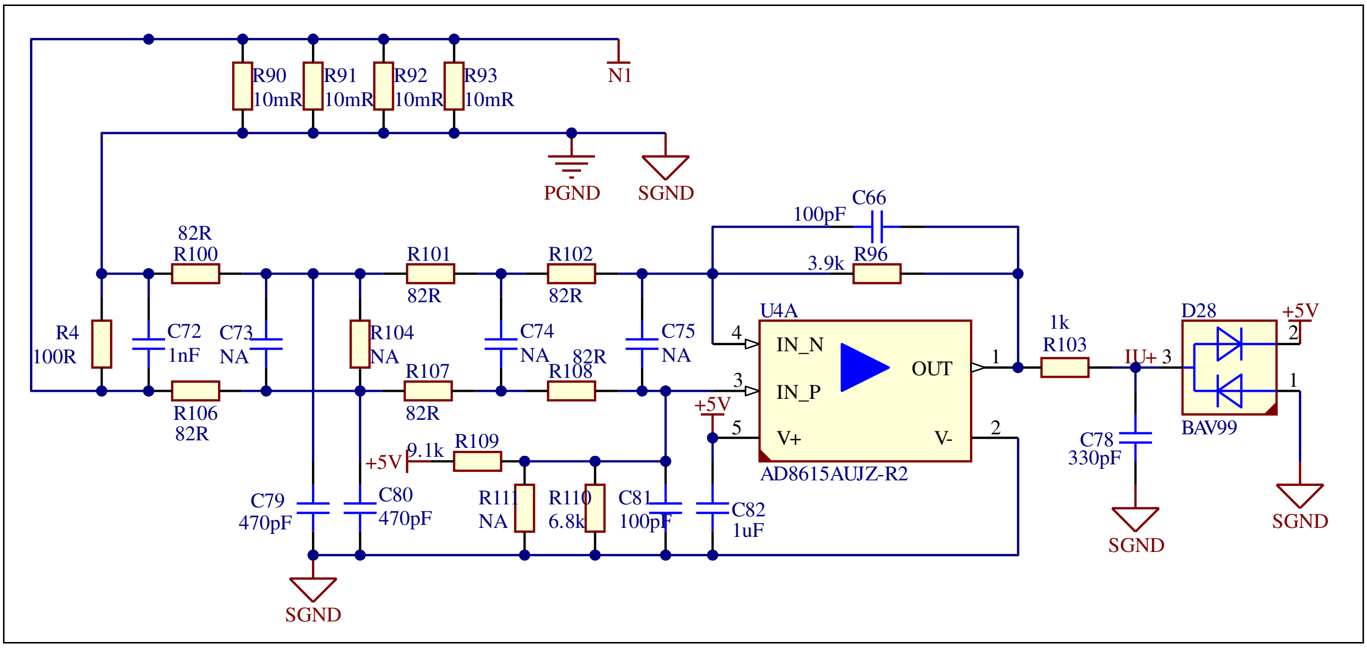


Figure 11 Current feedback circuit

2.2.6 NTC-thermistor configuration

The FP50R12KT4G combines a negative-temperature-coefficient (NTC) thermistor internally. The NTC thermistor-temperature curve is shown in Figure 12.

The NTC-thermistor resistance is 5 kΩ@25℃ and 493 Ω@100°C.

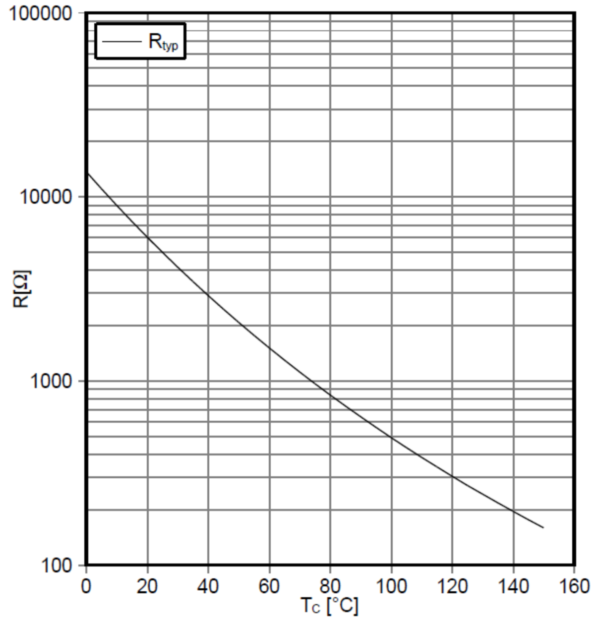


Figure 12 The NTC thermistor-temperature characteristic (typical)

There is a 4.87 kΩ pull-up resistor already located on the EVAL-M1-101T controller board. As the NTC-thermistor configuration in Figure 13, the sensing voltage VTH equals 4.14 V@25°C and 1.84 V@100°C. In MCEWizard the NTC-thermistor over-temperature voltage threshold is set to 1.84 V to protect the PIM from temperatures exceeding 100 °C.

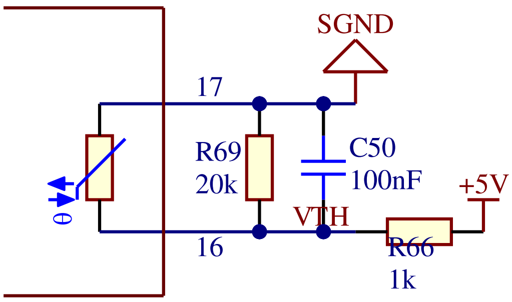


Figure 13 NTC-thermistor configuration

2.2.7 Auxiliary power supply

The auxiliary power supply circuit is located in the daughter board. It adopts the quasi-resonant flyback controller ICE5QSAG and CoolSiC™ 1700 V SiC MOSFET, IMF170R1k0M1, in a TO-263-7 package. The primary ground, and secondary +15 V and +5 V reference grounds are separated in the daughter board, but connected as a same net on the main board.

The controller board power supply is designed to +5 V instead of +3.3 V in order to improve the signal-noise ratio in high-power operations.

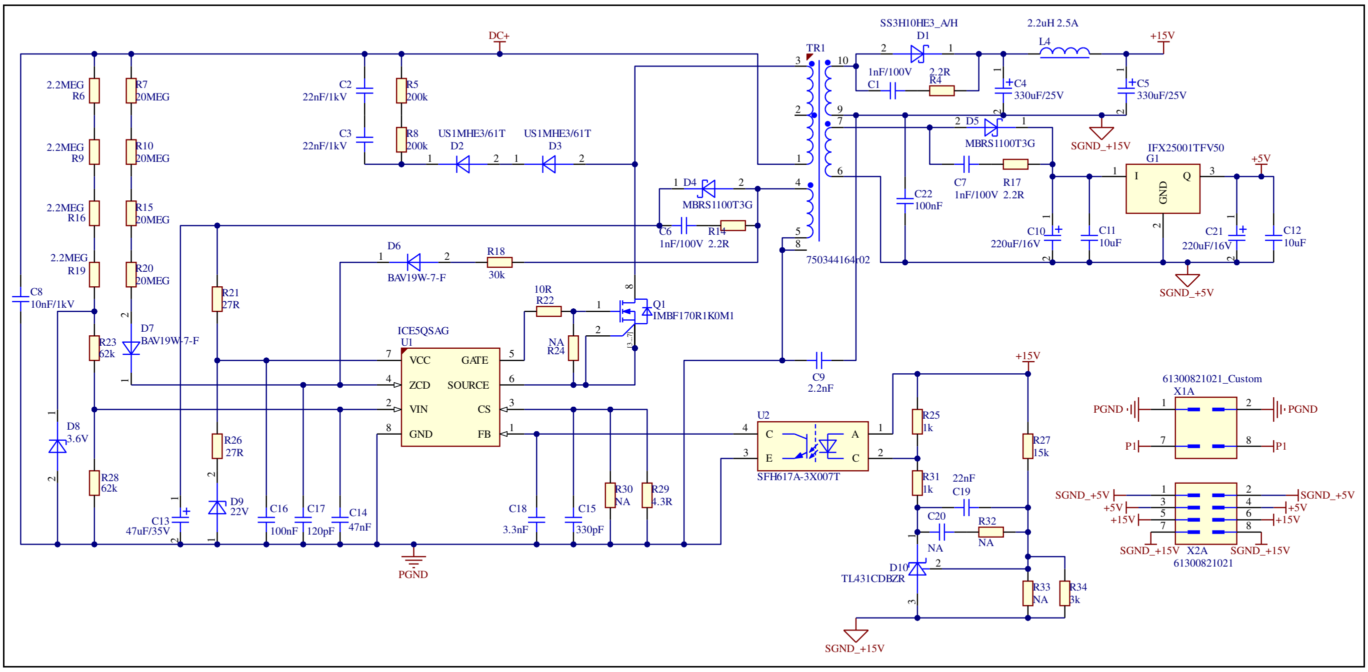


Figure 14 **Auxiliary power supply**

2.3 iMOTION™ development tool and software

The EVAL-M1-IR2214 can run a BLDC motor by connecting with an external controller board EVAL-M1-101T. The users have to properly configure the iMOTION™ development tool and software according to the system and BLDC motor parameters.

The MCEDesigner and MCEWizard as well as the supported files are available for download via the Infineon iMOTION™ website (http://www.infineon.com/imotion-software).

2.3.1 MCEWizard setup

The users have to enter the right parameters into the MCEWizard to run a BLDC motor.

The input for basic system configuration is shown in Figure 15. The pulse width modulation (PWM) frequency is set to 8 kHz, which is used widely for driving commercial air-conditioner (CAC) compressors.

The system configuration is shown in Figure 16.

All the necessary inputs for motor and control algorithms are listed in Figure 17.

Note: If using the current sensing data calculated in section 2.2.5 for items 83, 84, 85, the resistor R6 on the EVAL-M1-101T should be removed (no extra offset on the controller board).

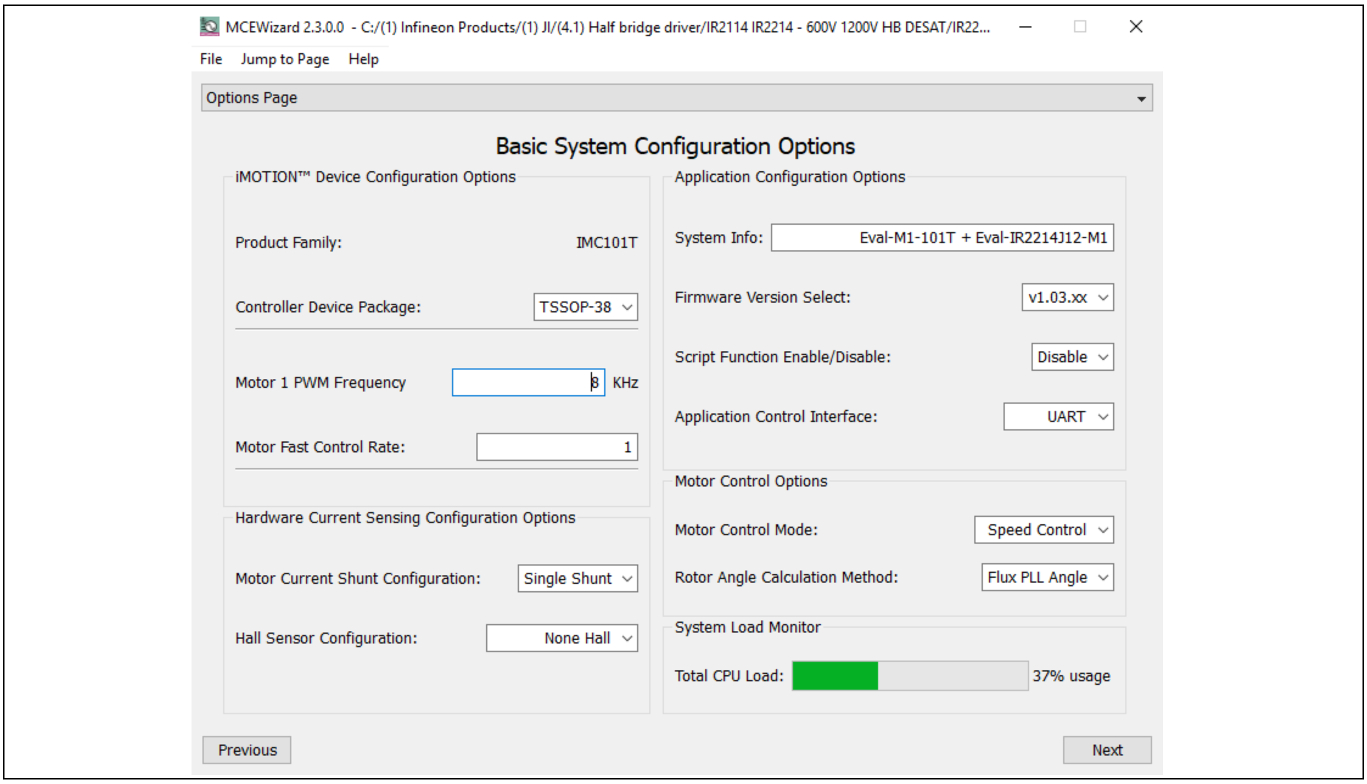


Figure 15 **Basic system configuration in MCEWizard**

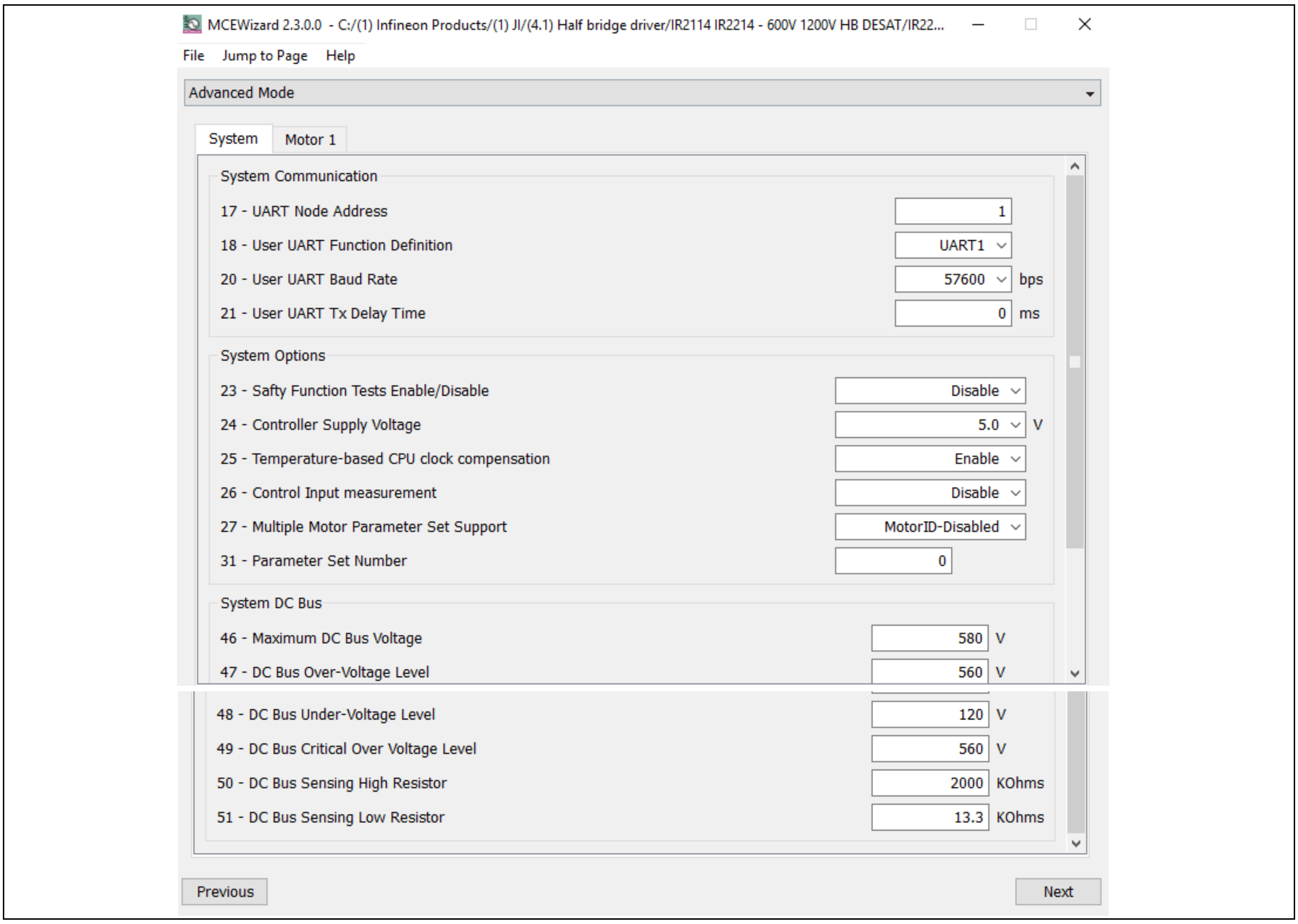
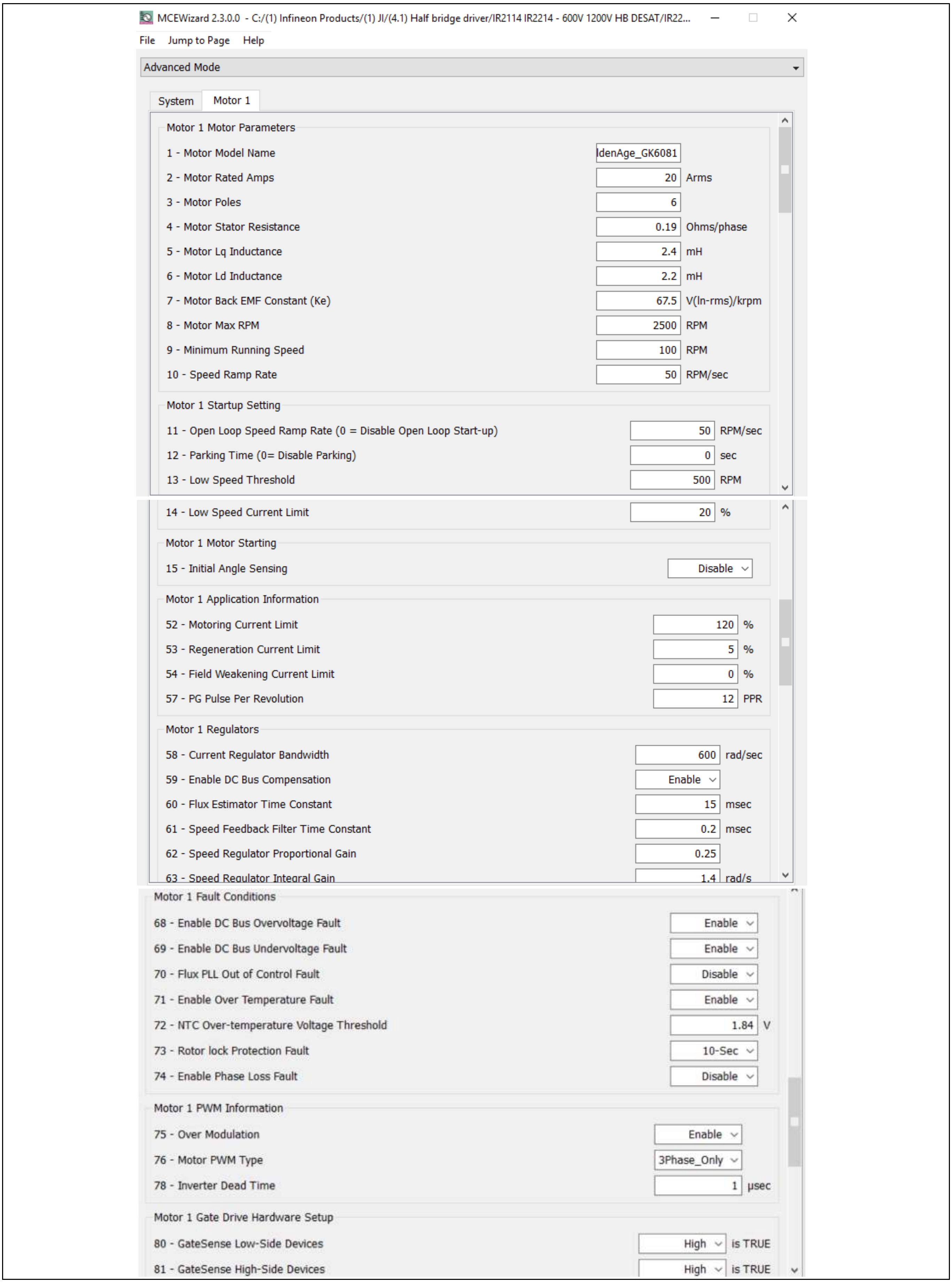


Figure 16 **System configuration in MCEWizard**


MCEWizard 2.3.0.0 - C:/(1) Infineon Products/(1) JI/(4.1) Half bridge driver/IR2114 IR2214 - 600V 1200V HB DESAT/IR22...
File Jump to Page Help
Advanced Mode
System Motor 1
Motor 1 Motor Parameters
1 - Motor Model Name IdenAge_GK6081
2 - Motor Rated Amps 20 Arms
3 - Motor Poles 6
4 - Motor Stator Resistance 0.19 Ohms/phase
5 - Motor Lq Inductance 2.4 mH
6 - Motor Ld Inductance 2.2 mH
7 - Motor Back EMF Constant (Ke) 67.5 V(ln-rms)/krpm
8 - Motor Max RPM 2500 RPM
9 - Minimum Running Speed 100 RPM
10 - Speed Ramp Rate 50 RPM/sec
Motor 1 Startup Setting
11 - Open Loop Speed Ramp Rate (0 = Disable Open Loop Start-up) 50 RPM/sec
12 - Parking Time (0= Disable Parking) 0 sec
13 - Low Speed Threshold 500 RPM
14 - Low Speed Current Limit 20 %
Motor 1 Motor Starting
15 - Initial Angle Sensing Disable
Motor 1 Application Information
52 - Motoring Current Limit 120 %
53 - Regeneration Current Limit 5 %
54 - Field Weakening Current Limit 0 %
57 - PG Pulse Per Revolution 12 PPR
Motor 1 Regulators
58 - Current Regulator Bandwidth 600 rad/sec
59 - Enable DC Bus Compensation Enable
60 - Flux Estimator Time Constant 15 msec
61 - Speed Feedback Filter Time Constant 0.2 msec
62 - Speed Regulator Proportional Gain 0.25
63 - Speed Regulator Integral Gain 1.4 rad/s
Motor 1 Fault Conditions
68 - Enable DC Bus Overvoltage Fault Enable
69 - Enable DC Bus Undervoltage Fault Enable
70 - Flux PLL Out of Control Fault Disable
71 - Enable Over Temperature Fault Enable
72 - NTC Over-temperature Voltage Threshold 1.84 V
73 - Rotor lock Protection Fault 10-Sec
74 - Enable Phase Loss Fault Disable
Motor 1 PWM Information
75 - Over Modulation Enable
76 - Motor PWM Type 3Phase_Only
78 - Inverter Dead Time 1 µsec
Motor 1 Gate Drive Hardware Setup
80 - GateSense Low-Side Devices High is TRUE
81 - GateSense High-Side Devices High is TRUE

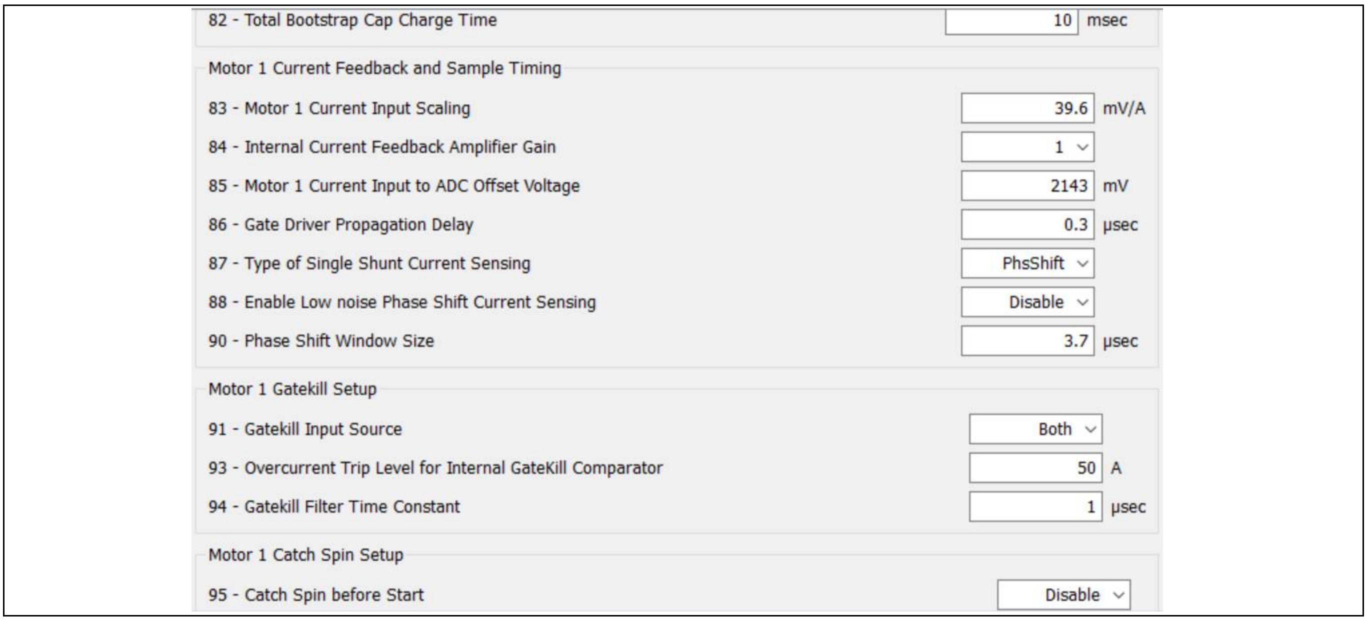


Figure 17 Motor and control algorithm configuration in MCEWizard

2.3.2 MCEDesigner setup

The MCEDesigner is a user interface to access or debug the controller board, see Figure 18.

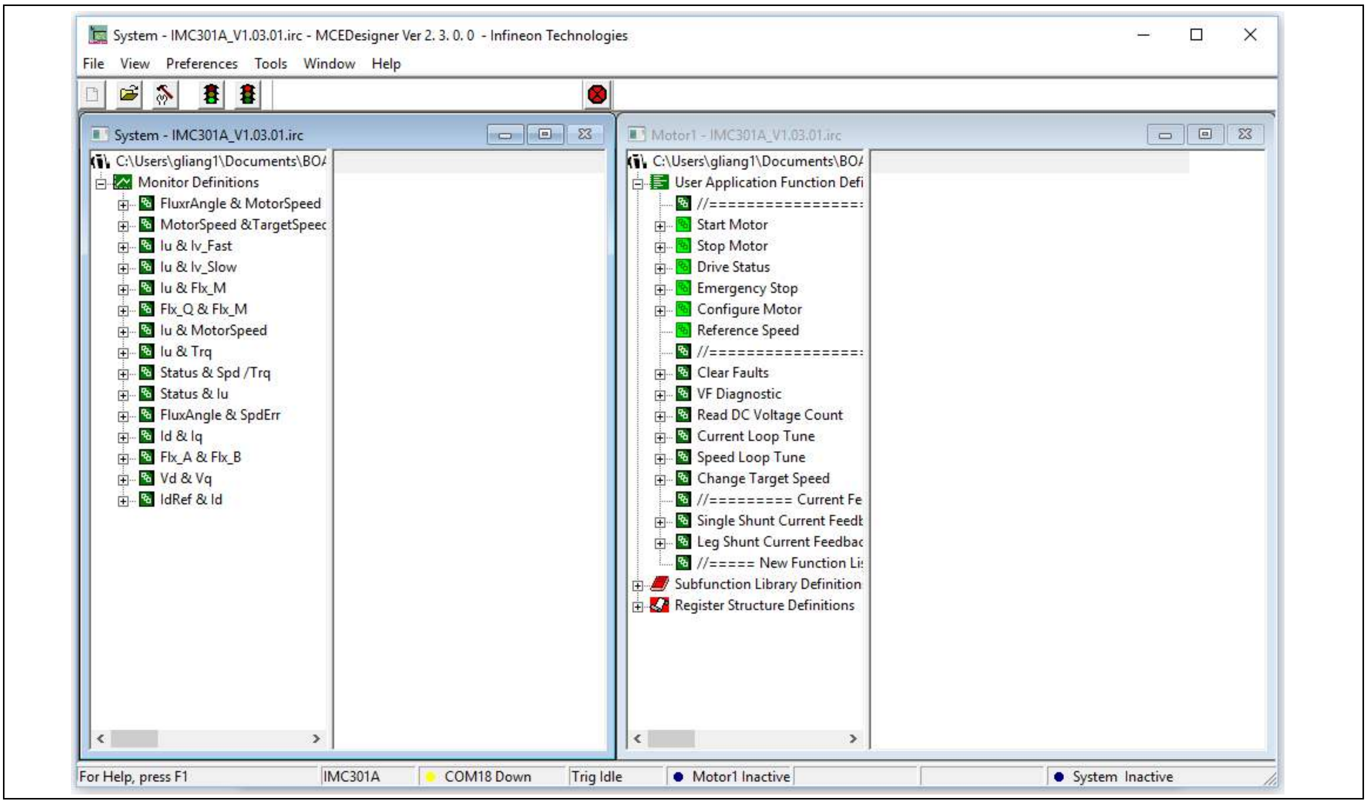


Figure 18 MCEDesigner main display for EVAL-M1-101T

3 System design

3.1 Schematics

The schematics of the EVAL-M1-IR2214 are shown in Figure 19 and Figure 20, respectively.

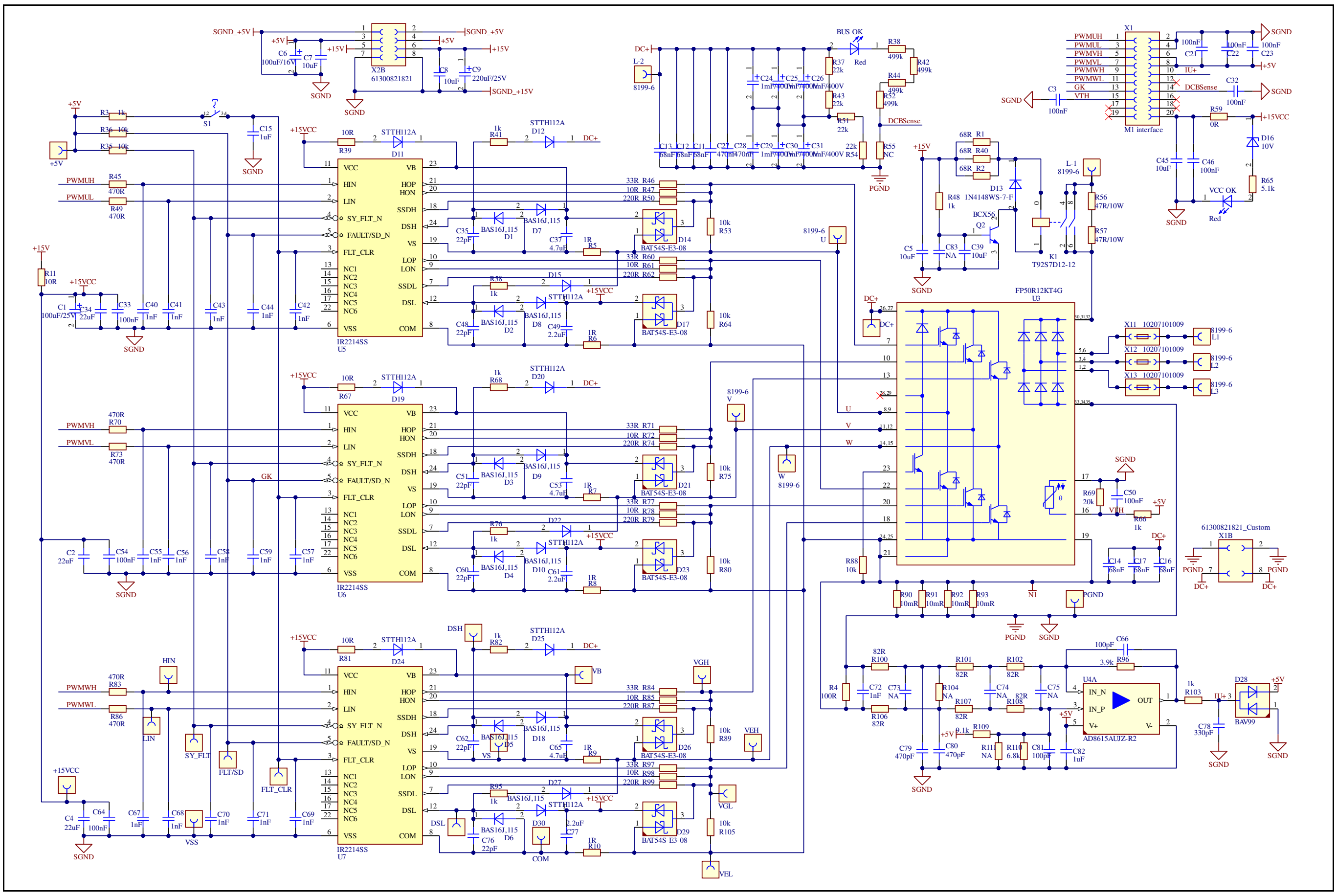


Figure 19 Power circuitry of the EVAL-M1-IR2214

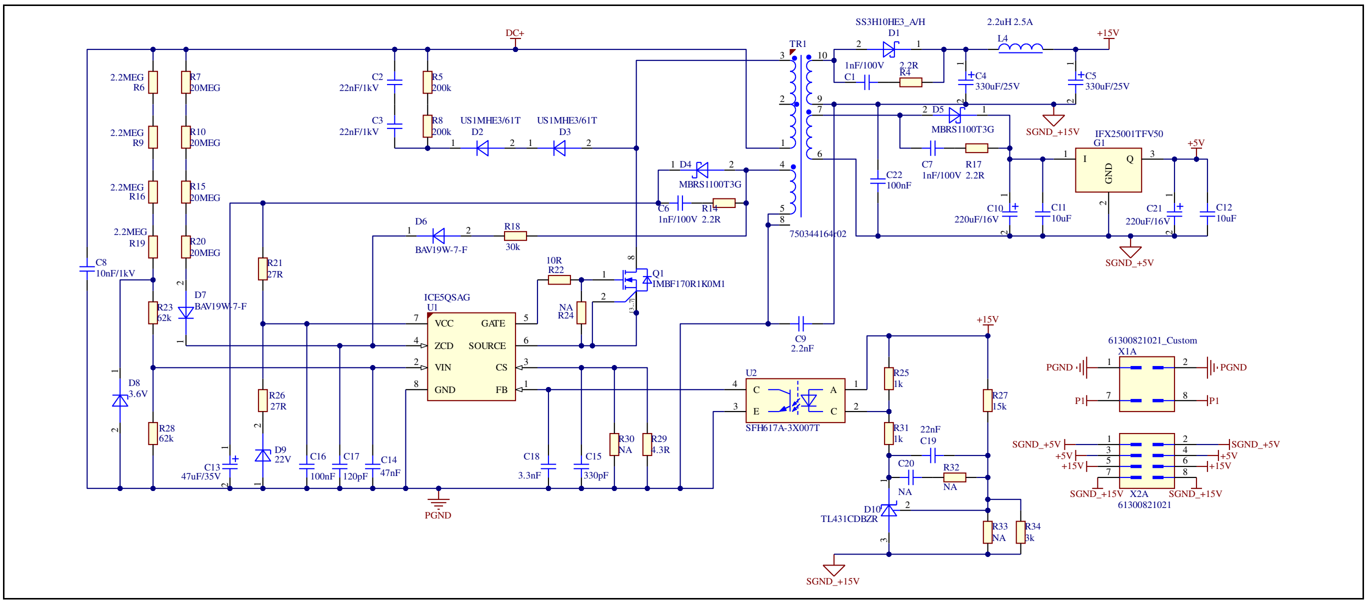


Figure 20 Auxiliary power supply circuitry of the EVAL-M1-IR2214

3.2 Layout

3.2.1 Layout details

The detailed layouts of the EVAL-M1-IR2214 are shown in Figure 21 to Figure 24.

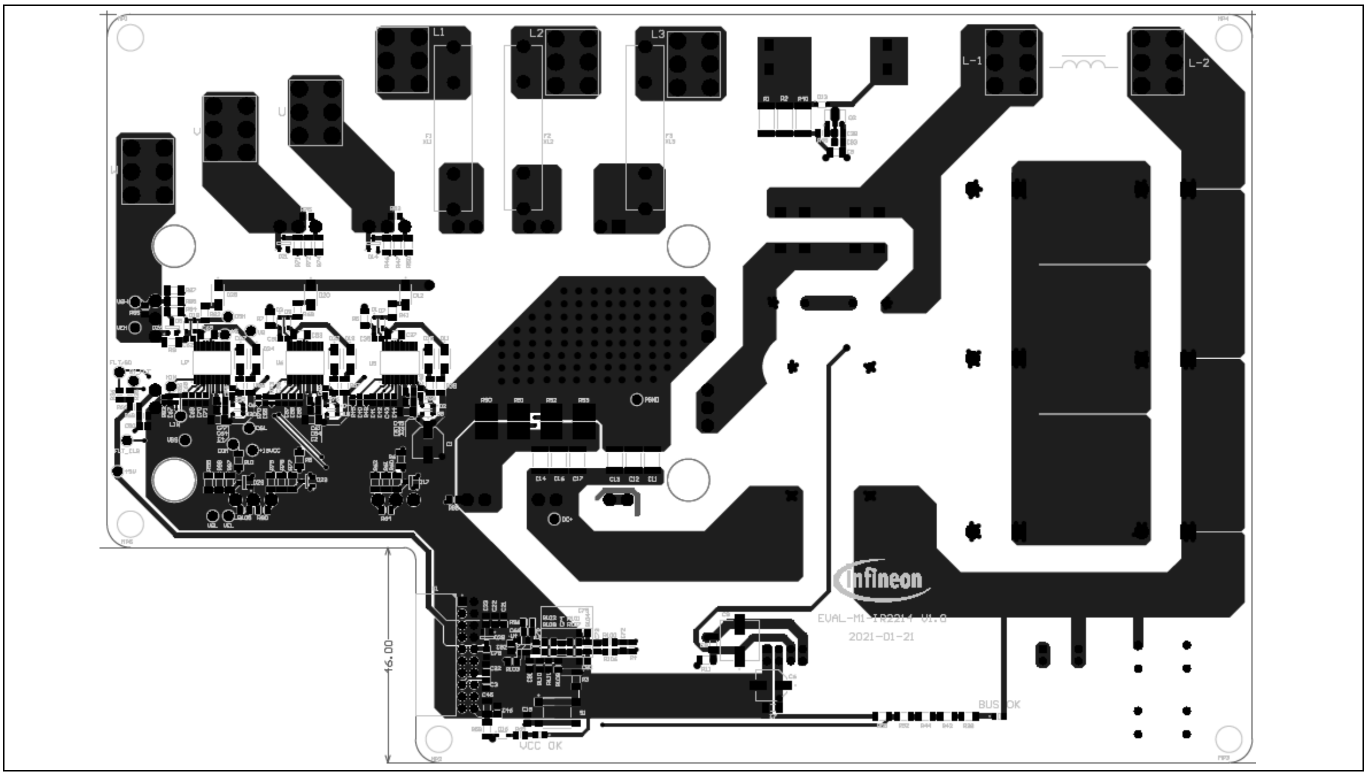


Figure 21 Power circuitry layout of the EVAL-M1-IR2214 – top view

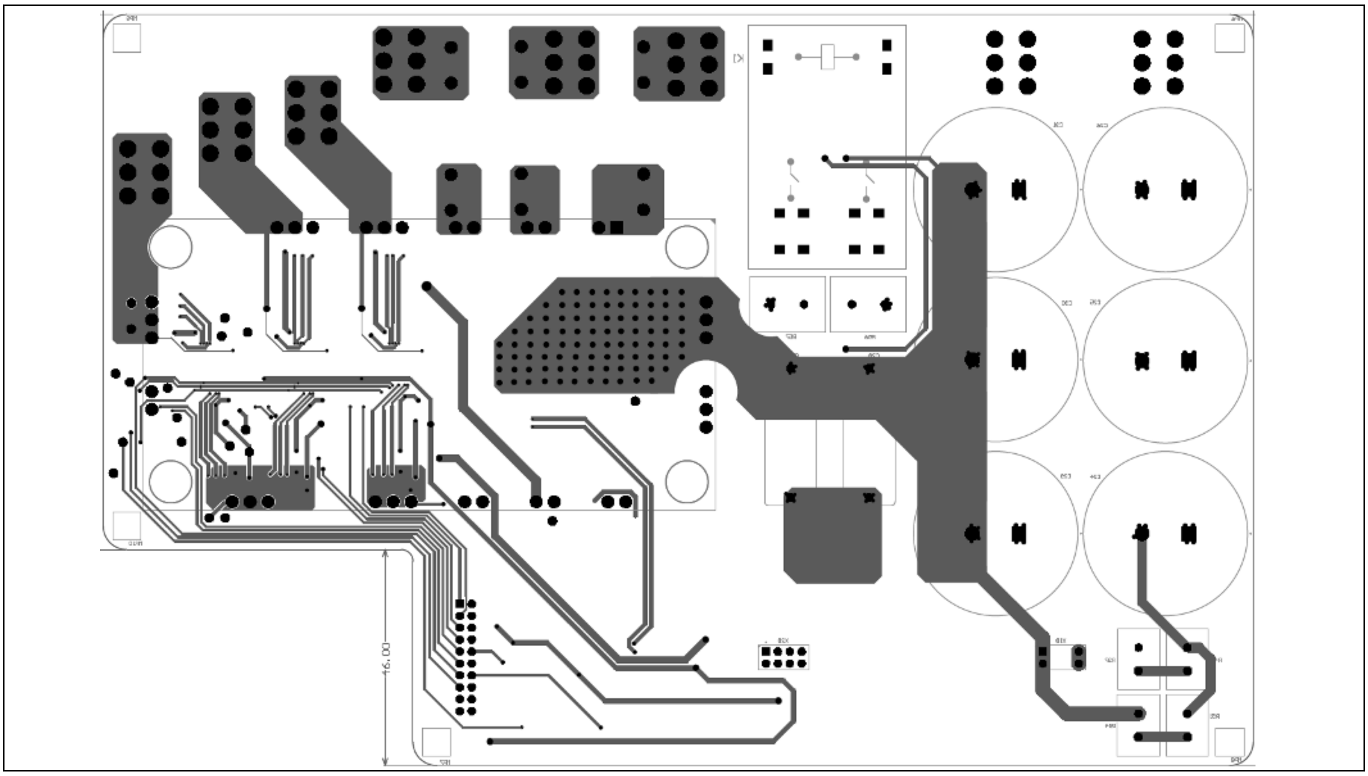


Figure 22 Power circuitry layout of the EVAL-M1-IR2214 – bottom view

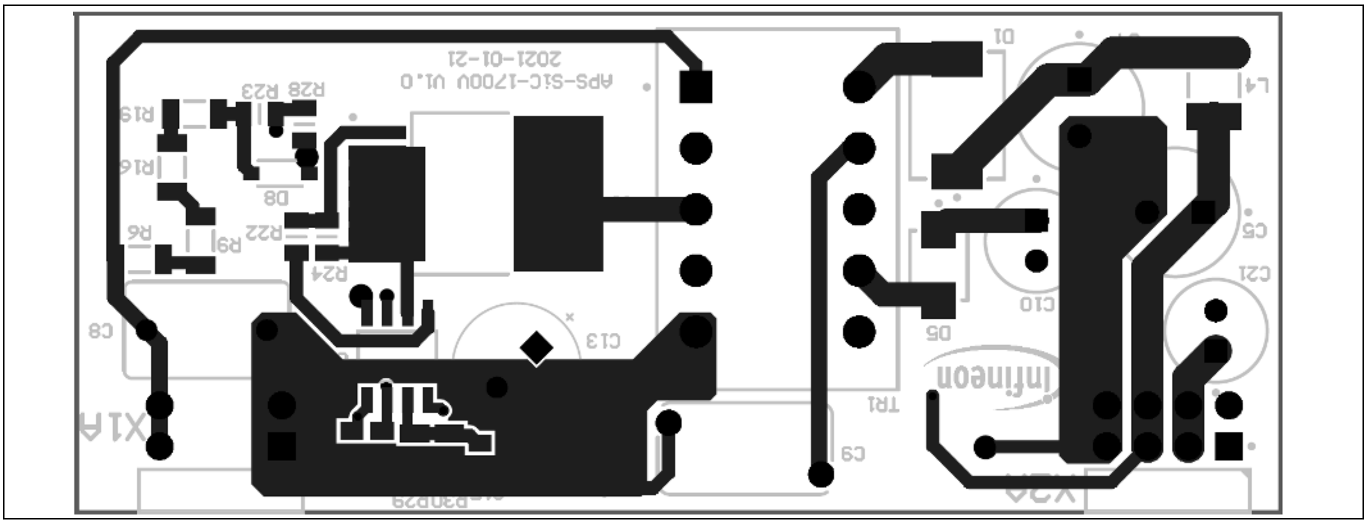


Figure 23 Auxiliary power supply circuitry layout of the EVAL-M1-IR2214 – top view

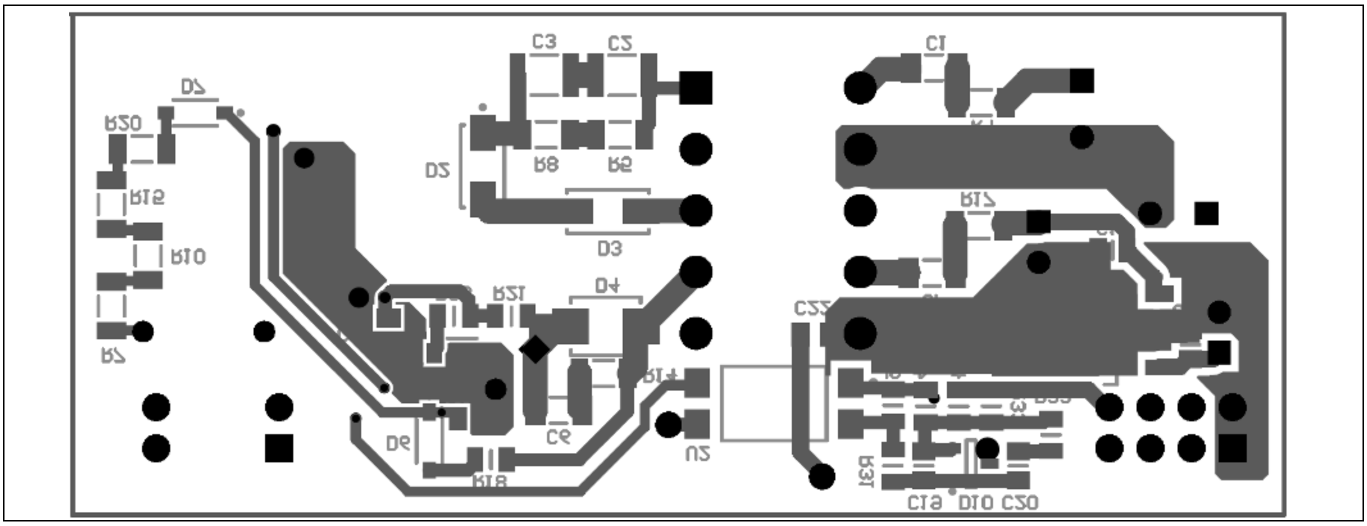


Figure 24 Auxiliary power supply circuitry layout of the EVAL-M1-IR2214 – bottom view

3.2.2 Layout guidelines

Some basic layout guidelines are listed 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 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.
- The clearance and creepage should be enough for the 540 V_{DC} bus voltage. In this layout the creepage is set to 5.3 mm which is compliant with the IR2214SS

3.3 Bill of material

The complete bill of material is available on the download section of the Infineon homepage. A log-in is required to download this material.

Table 3 lists the important components used in the EVAL-M1-IR2214.

Table 3 BOM of the most important/critical parts

No.	Ref designator	Description	Manufacturer	Manufacturer P/N
1	U5, U6, U7	1200 V half-bridge gate driver with desaturation protection	Infineon Technologies	IR2214SS
2	U3	1200 V/50 A EconoPIM™3 module	Infineon Technologies	FP50R12KT4G
3	U1	Quasi-resonant controller	Infineon Technologies	ICE5QSAG
4	Q1	1700 V/1 Ω SiC MOSFET in TO263-7 package	Infineon Technologies	IMBF170R1K0M1
5	G1	5 V/400 mA linear voltage regulator	Infineon Technologies	IFX25001TFV50
6	R90, R91, R92, R93	10 m Ω /5 W/1% SMD shunt resistor	Isabellenhuette	SMT-R010-1.0
7	C24, C25, C26, C29, C30, C31	400 V/1000 uF/35*60 mm/pitch 10 mm Al E-capacitor	Wurth	861021386035
8	U4A	20 MHz rail-to-rail operational amplifier	ADI	AD8615AUJZ-R2
9	RLY1	Two-pole 30 A/600 V_{AC} PCB mount relay	TE	T92S7D12-12
10	D11, D12, D19, D20, D24, D25	1200 V ultrafast rectifier	ST	STTH112A
11	D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D18, D30	75 V/250 mA high-speed switching diode	NXP	BAS16J
12	R37, R43, R51, R54	22 k Ω /5 W/5% vertical resistor	Yageo	SQM500JB-22K

3.4 Connector details

Table 4 Connectors

PIN	Label	Function
	L1	L1-phase of the power mains
	L2	L2-phase of the power mains
	L3	L3-phase of the power mains
	U	U phase-out to the motor
	V	V phase-out to the motor
	W	W phase-out to the motor
	J1	iMOTION™ MADK-M1 20-pin interface connector

4 System performance

4.1 Test results running a BLDC motor

The board is tested while running a BLDC motor as in the setup shown in Figure 25.

Test condition:

- Input: 380 Vac
- Phase-out current: 20 A_{rms}
- Room temperature
- BLDC motor: GK6081-6AC31-FE, I_O=20 A, U_i=135 V, test at speed=1200 r/min and 40 Nm
- Heatsink with forced-air cooling for the PIM

Note: After power-on, the pin 5 (FAULT/SD) of IR2214SS is initially in low state, thus disabling the IR2214SS drive output. The users have to press the push-button S1 on the board for 1 second and then release it. This step is necessary to clear the fault status and re-enable the IR2214SS.

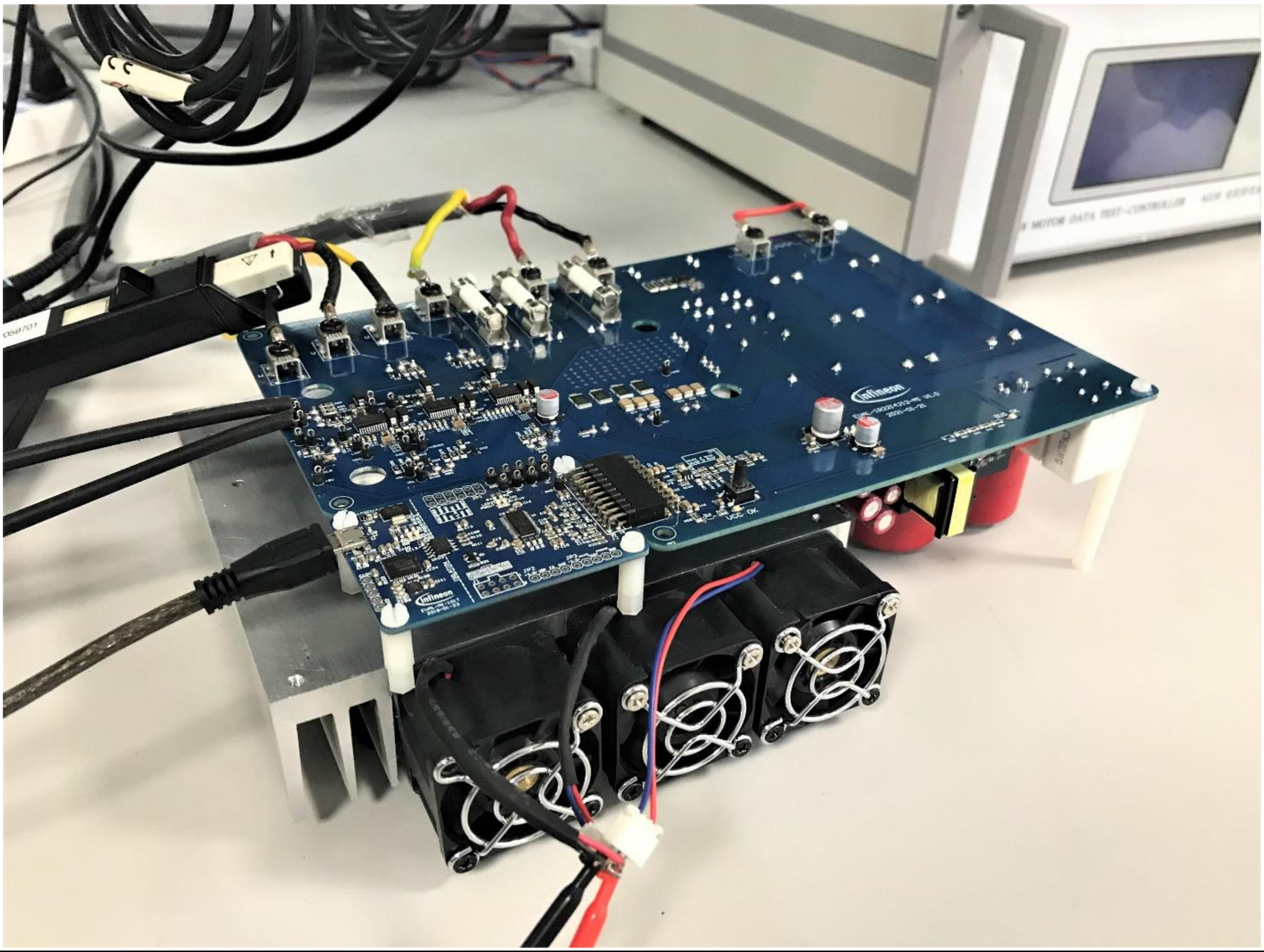


Figure 25 System setup for running a BLDC motor

Figure 26 shows the waveform when running a BLDC motor. The gate drive signals (V_{GE_HS}, V_{GE_LS}) indicate that no cross-conduction occurred. There are undershoots measured at the low-side desaturation detection pin 'DSL' to 'COM' ($V_{DSL-COM}$) while the low-side IGBT is turning ON, however, the undershoots are still within the -3 V limitation in the datasheet.

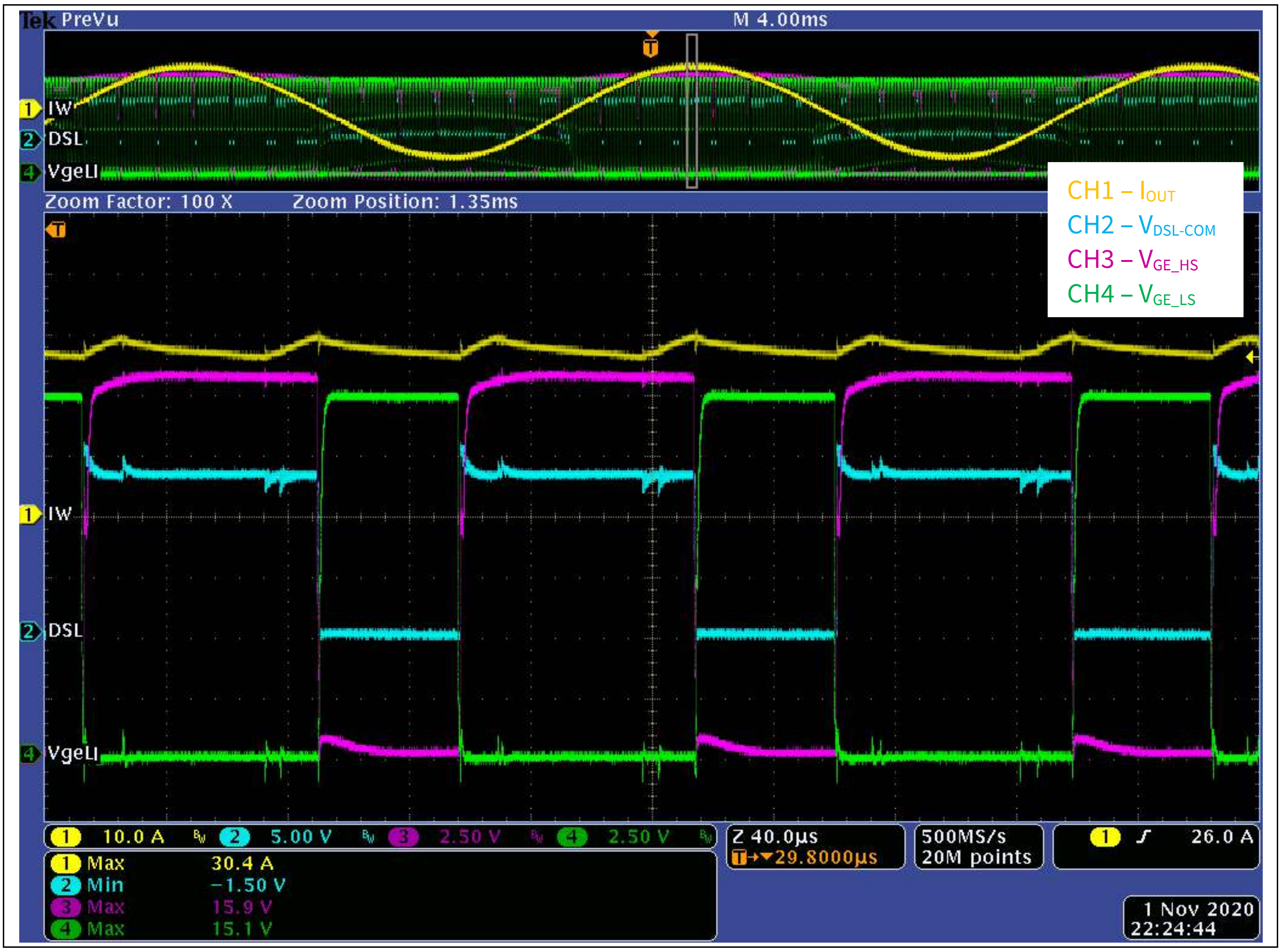


Figure 26 **Drive signal waveforms**

The desaturation protection is a remarkable feature of the IR2214SS. The W-phase, high-side IGBT is shorted by a short link to verify the short-circuit protection.

From Figure 27, once the desaturation is detected, the gate signal V_{GE_LS} starts to turn off in less than 3 uS. The turn off event is very soft due to the soft over-current shutdown function of the driver. The smooth turn-off prevents the transistor from destruction by over-voltage. The SY_FLT is also pulled low to report a failure of the desaturation which can be read by the other two IR2214SS.

Note: If desaturation is triggered, the users have to press the push-button S1 to re-enable the IR2214SS.

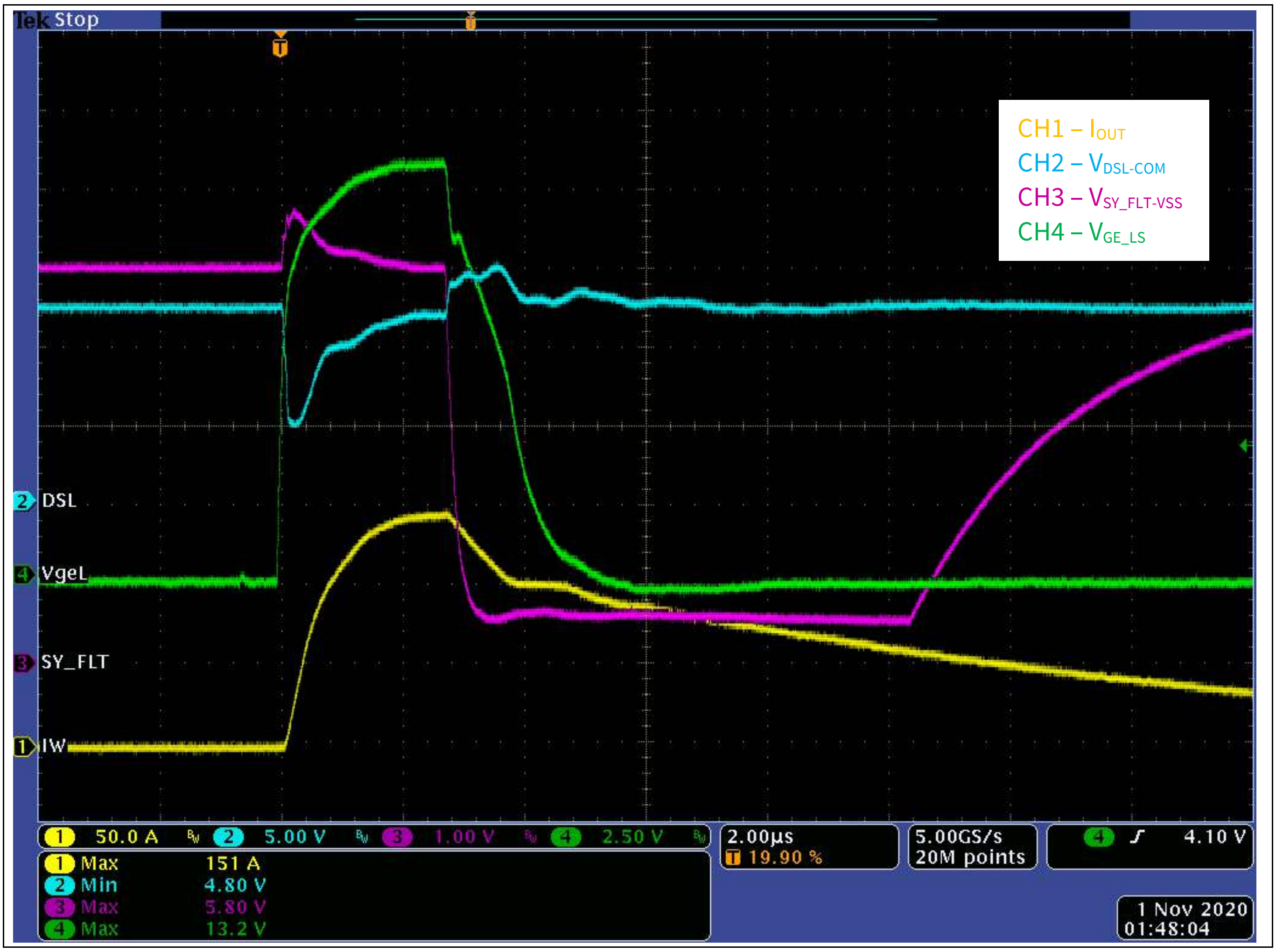


Figure 27 **Short-circuit protection**

4.2 Test results of the double-pulse test

As in the setup illustrated in section 2.1.2, the double-pulse test is performed to evaluate the board exceeding a 10 kW power rating in a real application.

Test condition:

- Bus voltage: 600 Vdc
- Switching current: 50 A
- Inductor: 200 uH

Figure 28 shows that the negative V_S and VSS transient referenced to COM are still in the IR2214SS safe-operation area.

Note: 1. To test the worst negative V_S and VSS transient, the inductor is connected between the W-phase mid-point (connector 'W') and ground PGND (test point 'PGND') on the board, and the double-pulse is entered in the HIN.

2. An isolated power supply +15 V should be added externally to power the V_{BS} (connects to the test points 'VB' and 'VS')

Figure 28 Negative V_S and VSS transient at 50 A switching current

5 References and appendices

5.1 Abbreviations and definitions

Table 5 Abbreviations

Abbreviation	Meaning
IC	Integrated circuit
IGBT	Insulated gate bipolar transistor
DC	Direct current
AC	Alternating current
BLDC	Brushless direct current
PIM	Power integrated module
SiC	Silicon carbide
PWM	Pulse width modulation
NTC	Negative temperature coefficient
EVAL	Evaluation board

5.2 References

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