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F3L030E07-F-W2_EVAL

Evaluation Board for Easy2B 3-Level Modules in NPC-Topology with 1ED020I12-F gate driver IC

IFAG IMM INP M AE

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Table of contents

Part number explanation

F3L 030 E07 -F -W2 _EVAL

- **_EVAL** → **Evaluation Board**
- **-W2** → **Package Easy2B**
- **-F** → **Functional isolation**
- **E07** → **Suitable for 650V module**
- **030** → **2 Amp driver ICs**
- **F3L** → **3 Level evaluation board**

Warnings

The described board is an evaluation board dedicated for laboratory environment only. It operates at high voltages. This board must be operated by qualified, skilled personnel familiar with all applicable safety standards.

1 Introduction

The Evaluation Driver Board F3L030E07-F-W2_EVAL for 3-Level Easy2B modules shown in Figure 1 was developed to support customers during their first steps designing applications with Easy2B 3-Level modules. For more details about the 3-Level topology, please refer to [1].
The board is available from Infineon in small quantities. The properties of this part are described in the datasheet chapter of this document, whereas the remaining paragraphs provide information intended to enable the customer to copy, modify and qualify the design for production, according to their own specific requirements.
The design of the F3L030E07-F-W2_EVAL was performed with respect to the environmental conditions described in this document. The requirements of lead-free reflow soldering have been considered during component selection. The design was tested as described in this document, but not qualified regarding manufacturing, lifetime or over the full ambient operating conditions.
The boards provided by Infineon are subjected to functional testing only.
Due to their purpose Evaluation Boards are not subjected to the same procedures regarding Returned Material Analysis (RMA), Process Change Notification (PCN) and Product Discontinuation (PD) as regular products.
See Legal Disclaimer and Warnings for further restrictions on Infineons warranty and liability.

2 Design features

The following sections provide an overview of the board including main features, key data, pin assignments and mechanical dimensions.

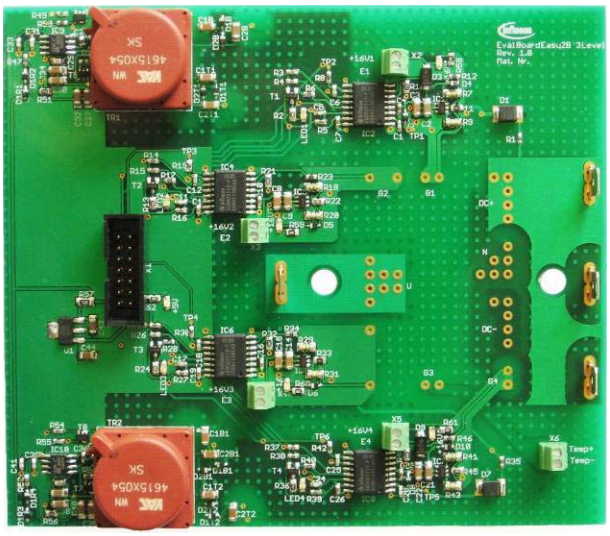

Figure 1 The Evaluation Board F3L030E07-F-W2_EVAL with Easy2B 3-Level module

2.1 Main features

The Evaluation Board F3L030E07-F-W2_EVAL as shown in Figure 1 contains four coreless transformers ICs 1ED020I12-F from Infineon and one Infineon Easy2B 3-Level module as one phase leg. Figure 2 shows the functional groups of the evaluation board.

The evaluation board provides the following main features as described in Figure 2:

- Functional isolation between high and low side utilizing coreless transformer technology.
- Short circuit protection and under voltage lock out.
- Active clamping protection for high and low-side IGBTs directly connected to the DC- bus bar.
- Active Miller Clamp.
- IGBT DCB temperature monitoring by NTC.
- Integrated and fully isolated power supply for each IGBT driver.
- +5V supply for the logic.

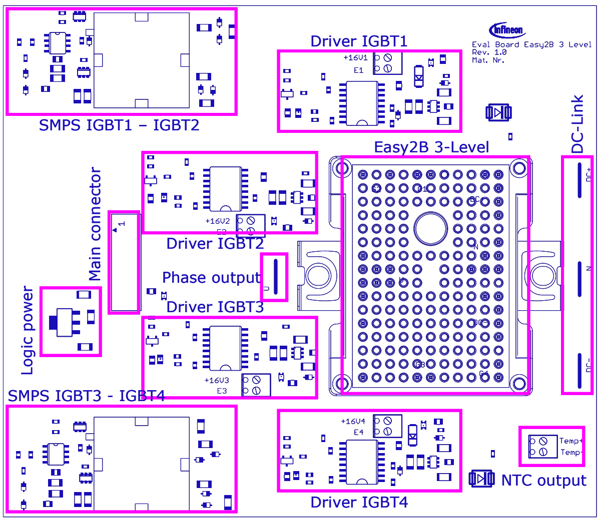

Figure 2 Functional groups of the evaluation board F3L030E07-F-W2

2.2 Pin assignments

All PWM signals and voltage supplies should be applied as listed in Table 1.

Table 1 Pin assignments of the connectors X1, X2, X3, X4, X5 and X6

Pin name	Pin function
X1-1	+IN_1
X1-3	+IN_2
X1-5	+IN_3
X1-7	+IN_4
X1-9	/RST
X1-13	+15V
X1-2, X1-4, X1-6, X1-8, X1-10 X1-14	GND
X1-11	/FLT_T
X1-12	/FLT_B
X2-1	+15V_1
X2-2	E1
X3-1	+15V_2
X3-2	E2
X4-1	+15V_3
X4-2	E3
X5-1	+15V_4
X5-2	E4
X6-1	TEMP+
X6-2	TEMP-

2.3 Mechanical dimensions

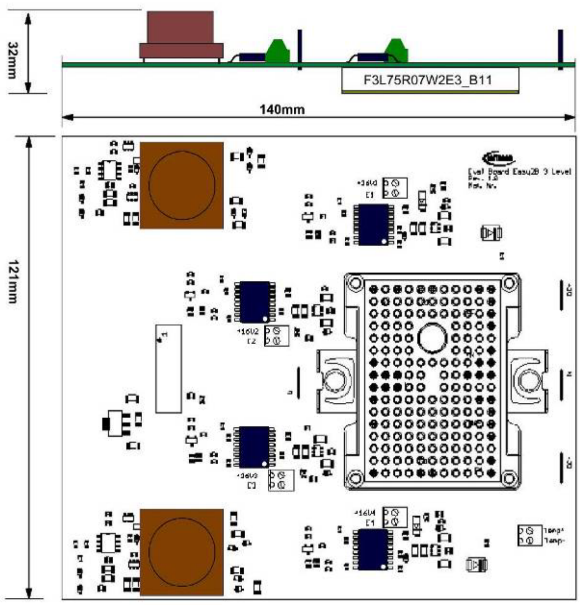

Figure 3 Mechanical dimensions of the F3L030E07-F-W2

3 Application note

3.1 Power Supply

The F3L030E07-F-W2_EVAL has two DC/DC converters, which generate four secondary isolated unipolar supply voltage sources of +15 V for each IGBT driver as shown in Figure 4. The driver voltages are independently generated by using one unipolar input voltage of +15 V. Furthermore, the power supplies are protected against gate-emitter short circuit of the IGBTs. In case of a DC/DC converter overload, the output voltage drops. The 1ED020I12-F[1] IGBT driver IC monitors the supply voltage and activates the UVLO[2] as soon as the supply voltage drops below the UVLO reference value of the 1ED020I12-F.

In order to assure the proper shutdown sequence of all IGBTs in the case of an under voltage of the driver ICs, it is important to switch off IGBT1 and IGBT4 first. There is one high voltage blocking diode in series with each +15V power line of the high and the low-side IGBT driver. This generates an additional voltage drop so that the external IGBT driver ICs closest to the DC-Link detect the **U**nder **V**oltage **L**ock **O**ut and shut down first.

The linear voltage regulator (U1) provides a second supply voltage of 5 V for the logic side of the evaluation board from the main +15V source. If the four generated +15V voltage sources on board are not needed, each driver could be externally supplied by the connectors X2, X3, X4 and X5. In this case the powering of the SMPS can be interrupted by removing the diodes D1R1 and D1R3, shown in Figure 15, 16.

The Evaluation board of Easy2B 3-Level module has three terminals DC+, NCLAMP and DC- for the connection to an external DC-Link voltage. The phase output is connected to the terminal OUT.

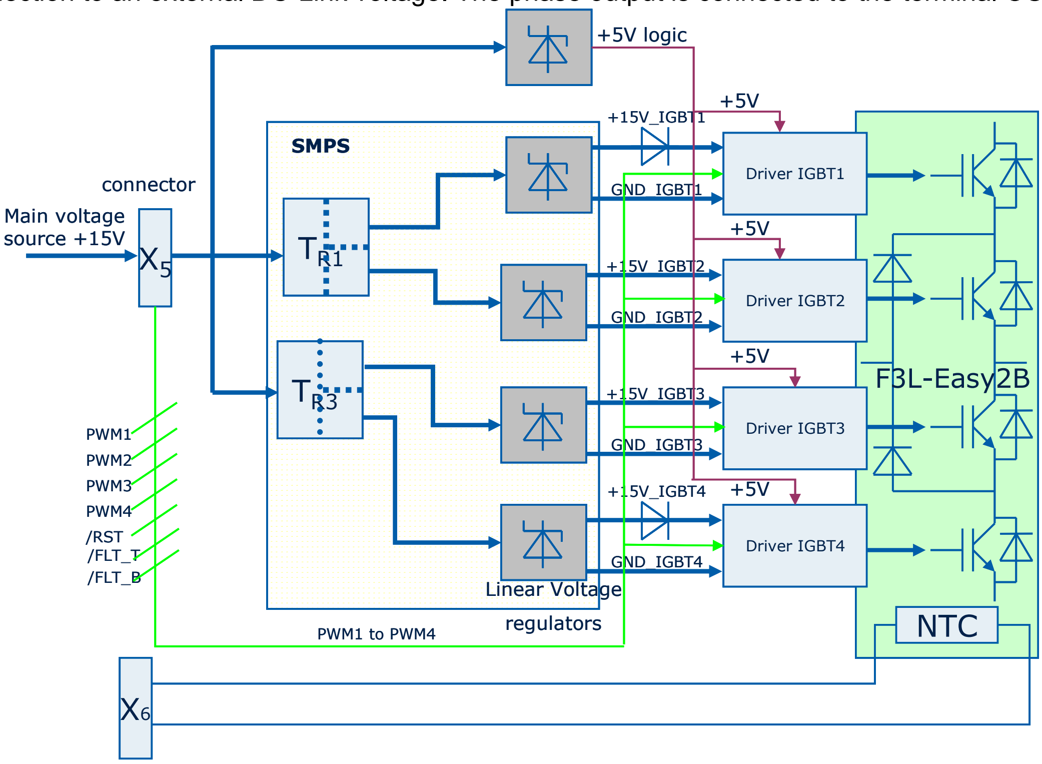

Figure 4 Principle diagram of the F3L030E07-F-W2_EVAL

[1] Infineon IGBT Gate Driver IC
[2] Under Voltage Lock Out

3.1 Input logic – PWM signals

The F3L030E07-F-W2_EVAL Driver Board is designed for one leg Easy2B 3-Level IGBT module configuration; therefore it is necessary to connect four separate PWM signals for IGBT1 to IGBT4.

The schematic in Figure 5 shows the driver circuit. IN+ is used as signal input with +5V positive logic. IN- is connected to ground.

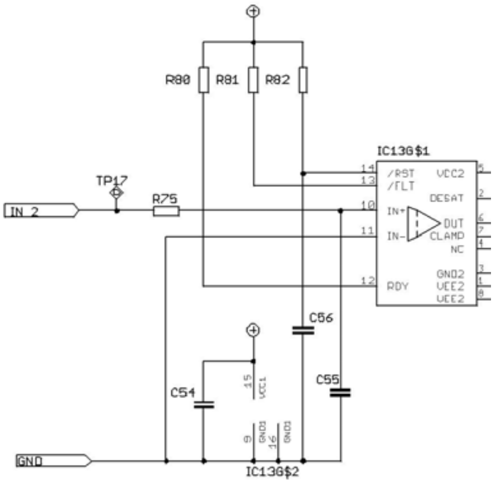

Figure 5 Schematic of the input circuit for a single driver for one IGBT

3.2 Booster

Complementary transistors are used to amplify the driver ICs signal as shown in Figure 6. This enables the driving of IGBT's that require more current than the IC can deliver. One NPN transistor is used for switching the IGBT on and one PNP transistor for switching the IGBT off.

The transistors are dimensioned to have enough peak current to drive the 650 V Easy2B modules. Peak current can be calculated according to equation (2):

$$I_{peak} = \frac{\Delta V_{out}}{R_{G_{\mathrm{int}}} + R_{G_{ext}} + R_{Driver}} \tag{2}$$

$R_{Driver} \approx 0.7\Omega$ is the internal output resistance of the booster

R_{Gext} is the external gate resistor of the IGBT module

R_{Gint} is the internal gate resistor of the IGBT module

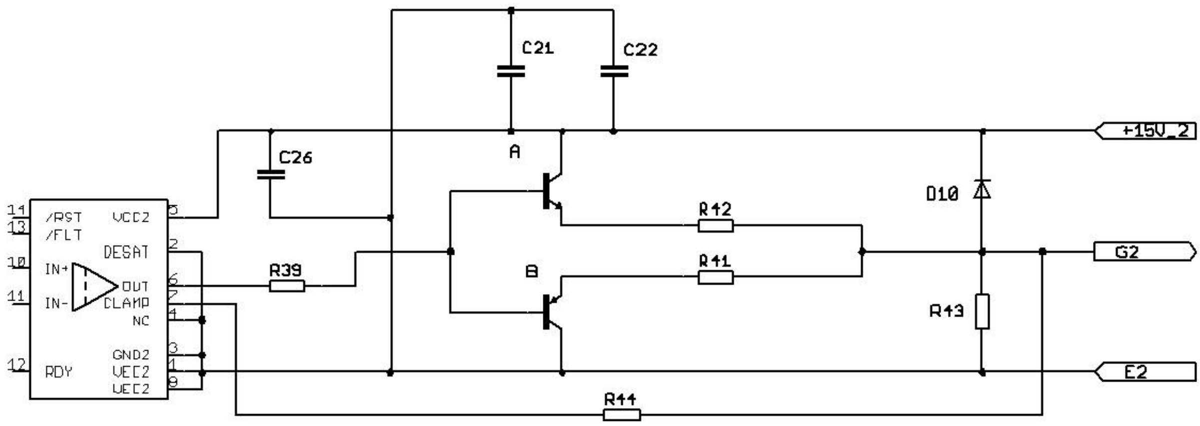

Figure 6 Booster

3.5 Short circuit protection and clamp function

The short circuit protection of the Evaluation Driver Board is realized by the detection of a defined saturation voltage level of IGBT1 and IGBT4. During the on state of the IGBT module, the saturation voltage U_{CE} is less than 9V. If a short circuit occurs, the collector current and the saturation voltage U_{CE} increase. With the IGBT in the commanded on state if the collector emitter voltage rises and the voltage on the DESAT pin of the driver IC reaches 9V a short circuit is detected and the output is driven low. The short circuit is reported on the control side as /FLT. An active low reset signal is needed to reactivate the 1ED020I12-F driver IC. The short circuit monitoring of IGBT2 and IGBT3 is not necessary.

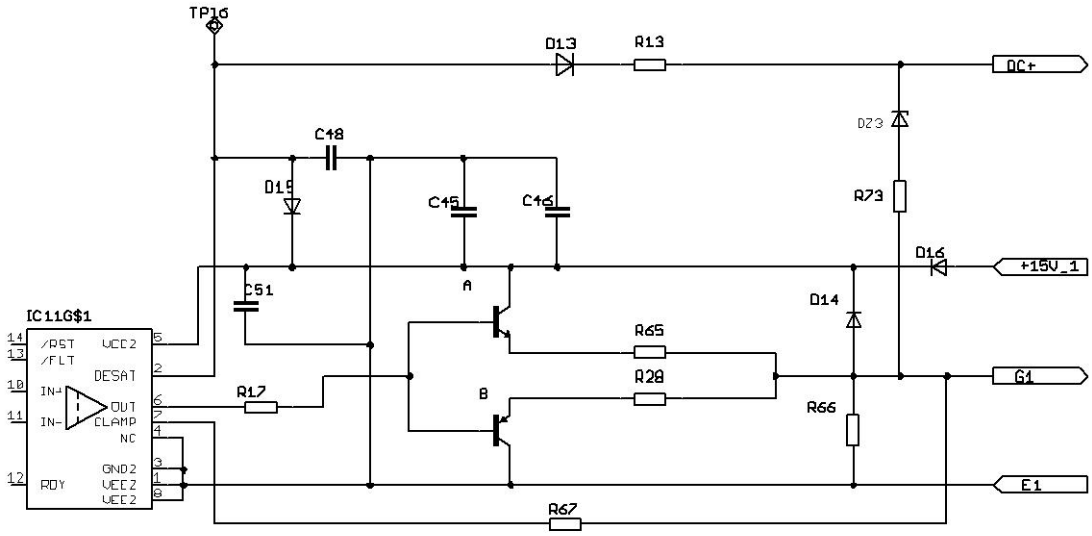

Figure 7 Desaturation protection and active clamping diodes

The evaluation driver board contains an active clamping function. If the voltage across the IGBT exceeds the zener voltage of ZD3 the clamp will be activated and the gate voltage will increase. In case of a short circuit the saturation voltage U_{CE} will rise and the driver detects a short circuit. The IGBT has to be switched off. There will be an overvoltage due to the stray inductances of the module and DC-Link. This overvoltage has to be lower than the maximum IGBT blocking voltage. If a higher operation DC-link voltage is needed it is important to adjust the breakdown voltage of the clamping diodes DZ1 and DZ2 shown in Figure11 and 14 to avoid the conduction of the active clamp circuit during normal switching conditions.

The dc capacitor bank must be placed as close as possible to the evaluation Board to avoid undesirable stray inductance in the DC power supply line

3.6 Active Miller Clamp

Due to the economical point of view, it is mostly preferred to supply the IGBT gate driver for low power converters with an unipolar voltage 15V/0V instead of utilizing a bipolar supply voltage e.g. +15V/-15V. In this solution, the effect of a parasitic turn on can not be avoided without an additional effort. The parasitic turn on emerges, when i.e. the upper IGBT T1 in a half bridge is switched on and takes over the commutation current of the free wheeling Diode of T2. At the same time the voltage across the lower IGBT T2 increases and a high dV_{CE}/dt appears. The current flows through the parasitic Miller capacitor C_{CG} of the lower IGBT, the gate resistors R_{Gint}, R_{Gext} and internal driver gate resistor, R_{DRIVER_int}. Fig.8 shows the current flow through the capacitor C_{CG}.

$$I_{CG} = C_{CG} * \frac{dV_{CE}}{dt}$$

This current creates a voltage drop across the resistors. If this voltage exceeds the IGBT gate threshold voltage, a parasitic turn-on occurs [4].

One of the features of the 1ED020I12 IGBT gate driver is the “Active Miller Clamping”, which is a very effective solution to suppress the parasitic turn on. The Miller Clamp reduces the voltage drop caused by the Miller current passing through the gate circuit during a high dV/dt situation. Therefore, the use of a negative supply voltage can be avoided in many applications. During turn-off, the gate voltage is monitored and the clamp output is activated when the gate voltage goes below 2V (related to VEE2).

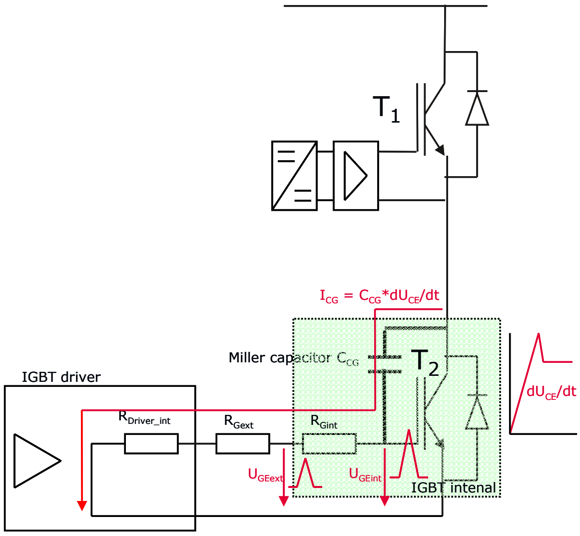

Figure 8 Parasitic turn-on on the bottom IGBT stray inductance

3.7 Fault output

When a short circuit occurs, the desaturation protection circuit of the 1ED020I12-F reacts and the IGBT is switched off. The fault is reported to the primary side of the driver as long as there is no reset signal applied to the driver. The /FLT signal is active low, the according schematic is shown in Figure 9.

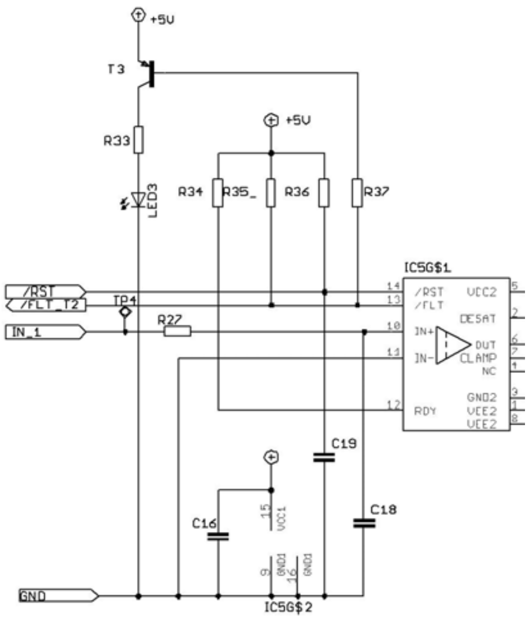

Figure 9 Fault output and Reset for a single driver

The fault signal will be in low state in case of a short circuit until /RST is pulled down.

3.8 Temperature measurement

The IGBT DCB temperature can be monitored by proper usage of the NTC resistor built into the module. The evaluation of the temperature information requires an external circuit. Further information on using the NTC including the NTC characteristics is described in application note AN2009-10 [2].

Notice:

This temperature measurement is not suitable for short circuit detection or short term overload and may be used to protect the module from long term overload conditions or malfunction of the cooling system.

It is recommended that the design incorporate functional isolation between the NTC and any low voltage control circuits.

3.9 Switching losses

The setup used for this application note varies from the setup used to characterize the devices and the following aspects have to be taken into consideration

DC-link inductance:

The DC-link inductance of the setup used for these tests has a value of approximately 60nH for all modules investigated here in contrast to the values of 35nH used for device characterization (see device datasheets for details). For a detailed discussion on the impact of DC-link inductance on switching losses please refer to [3].

Gate voltage:

This evaluation board provides a gate voltage of 0 V for turning off and 15 V for turning on whereas characterization is done with a driver providing +/- 15 V of gate voltage.

Gate driver output impedance: According to IEC 60747-9 for characterization of an IGBT the driver used should be an ideal voltage source as far as possible. For the Evaluation Board a driver output stage has been chosen that considers board space as well as cost constraints. Therefore it cannot provide close to zero output impedance.

All aspects discussed above have an impact on the switching speed of the module and hence also on the switching losses. Figure 10 shows an example of the turn-on and turn-off behavior of an F3L150R07W2E3_B11 module.

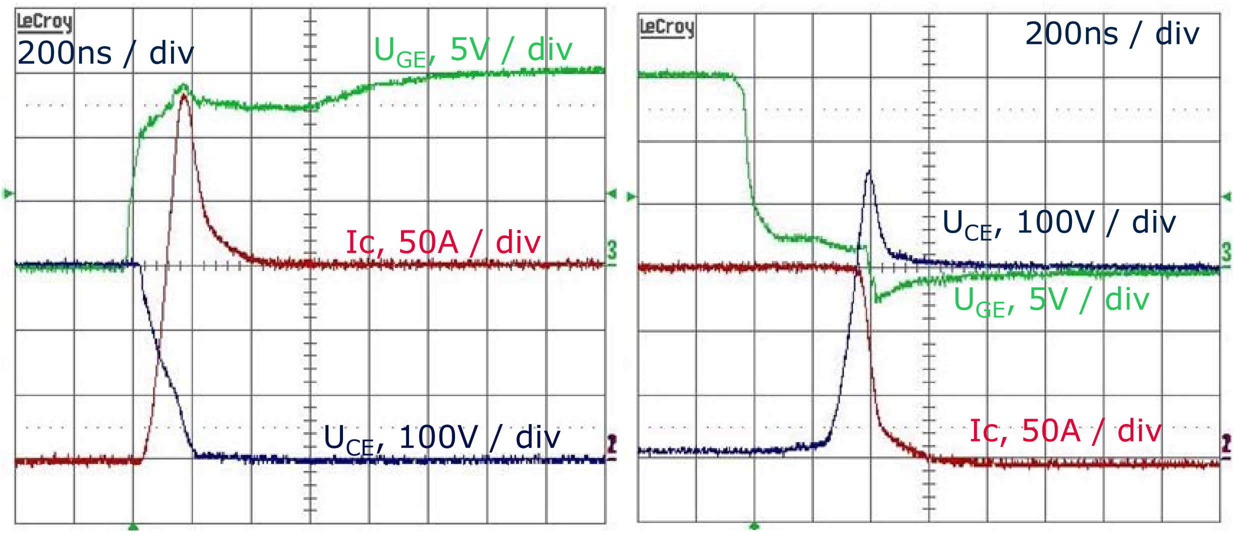

Figure 10 Turn-on and Turn-off curve of T4 with F3L150R07W2E3_B11 module

4 Schematic and Layout of F3L030E07-F-W2_EVAL

To meet the individual customer requirements and make the evaluation board simple for further development or modification, all necessary technical data: schematics, pcb layout and component data are included in this chapter

4.1 Schematic

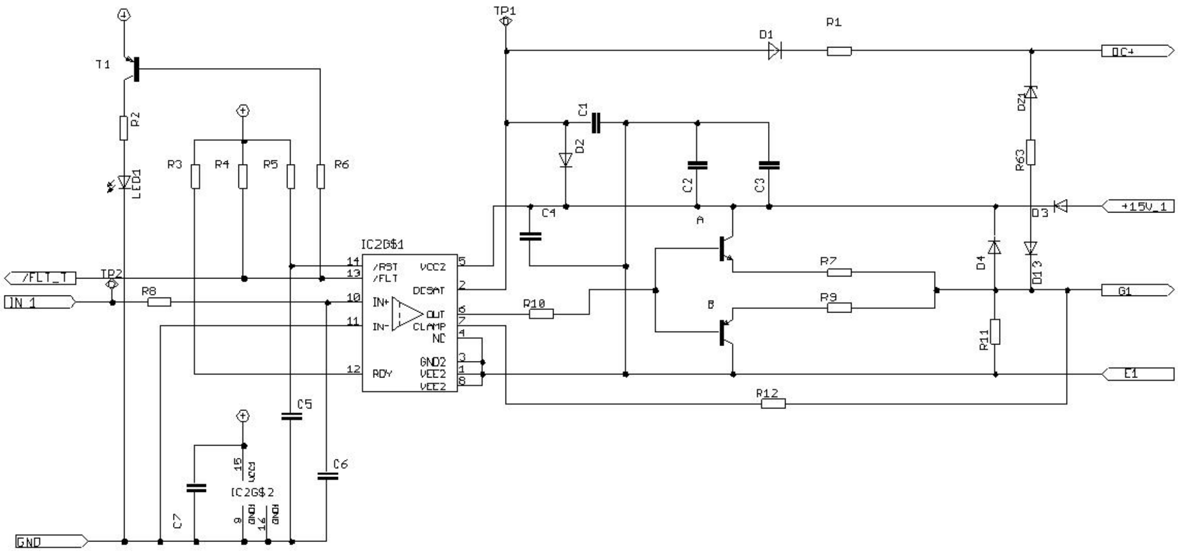

Figure 11 Driver IGBT1

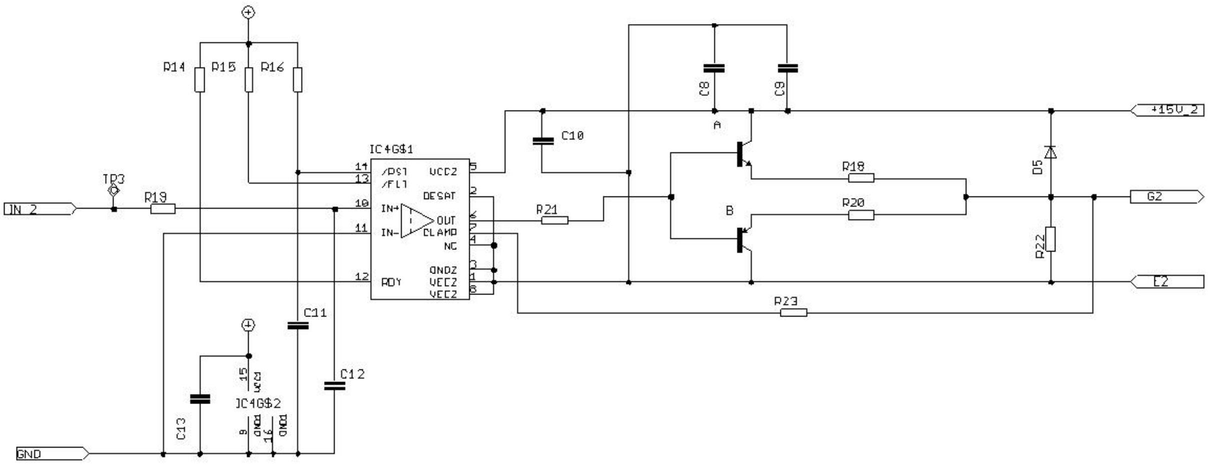

Figure 12 Driver IGBT2

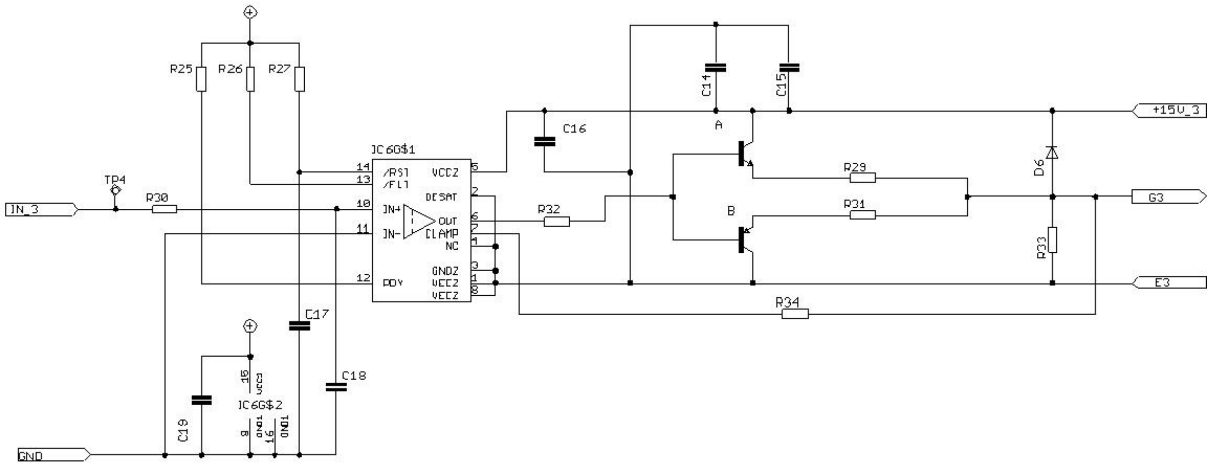

Figure 13 Driver IGBT3

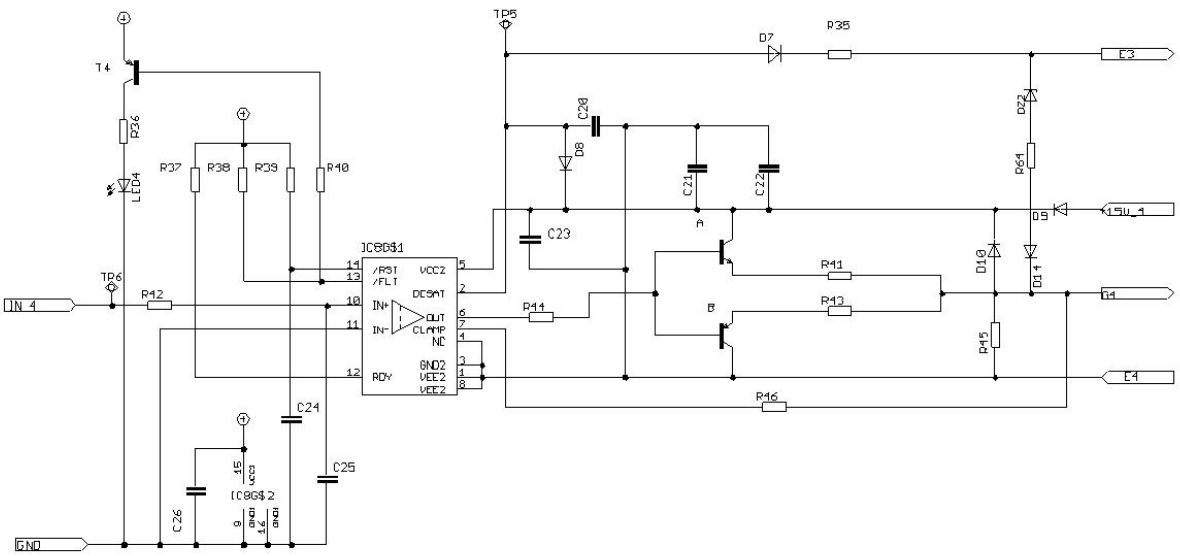

Figure 14 Driver IGBT4

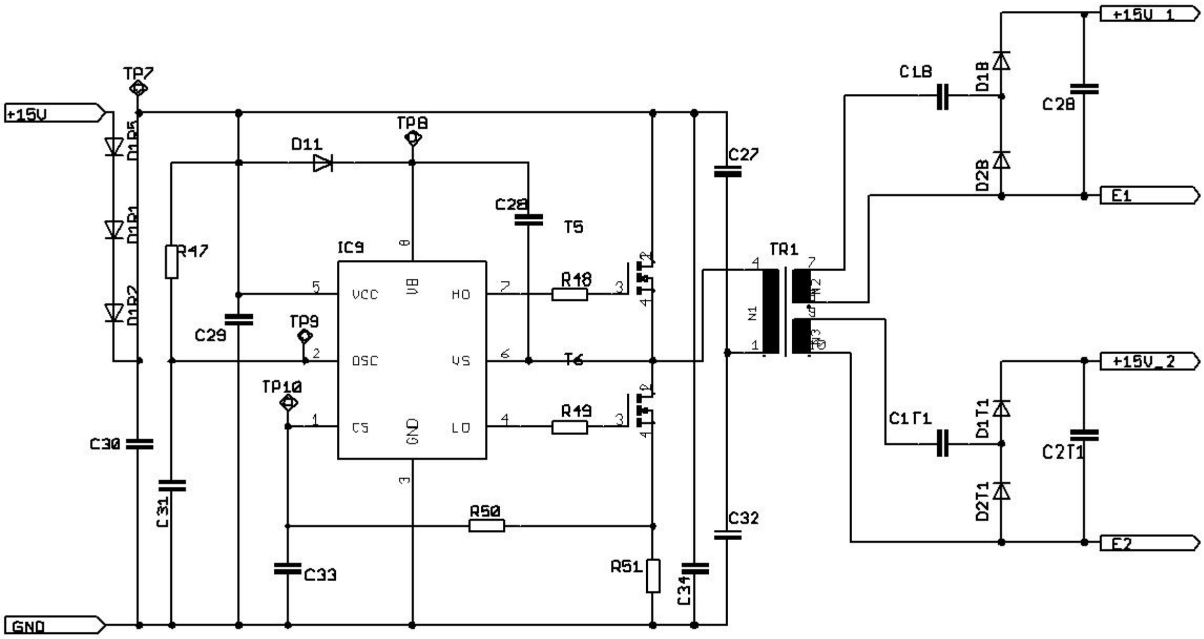

Figure 15 Driver DC/DC converter IGBT1 and IGBT2

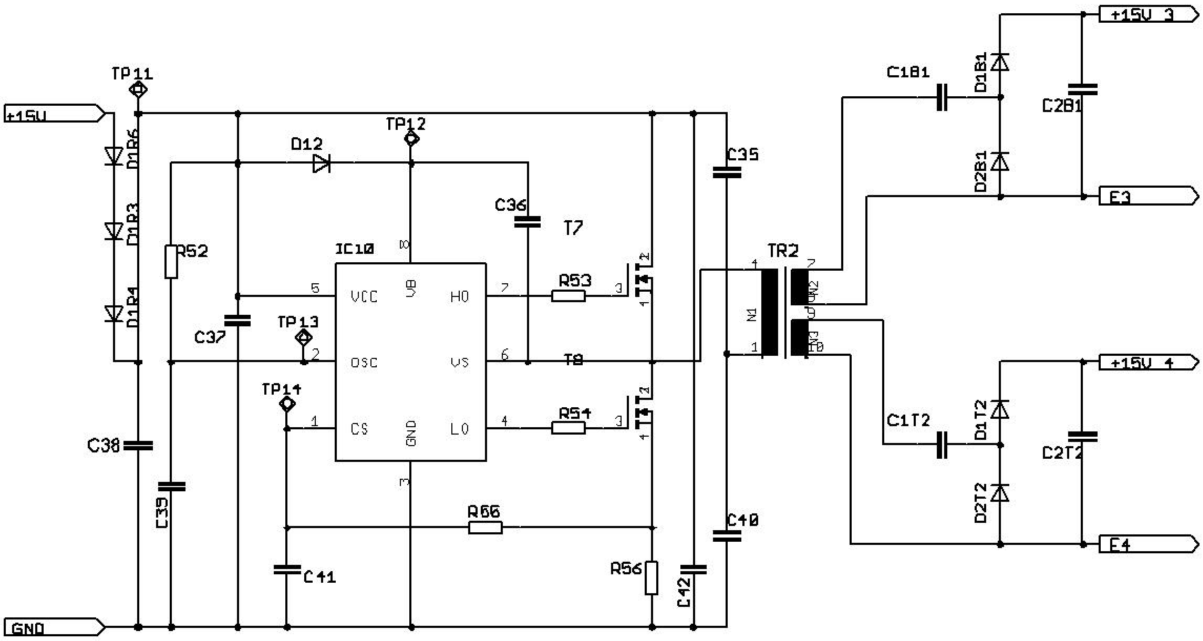

Figure 16 Driver DC/DC converter IGBT3 and IGBT4

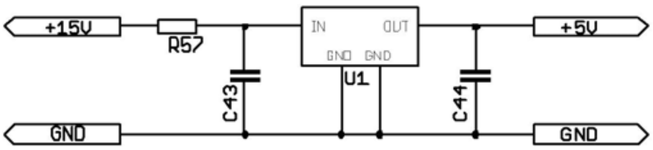

Figure 17 Logic supply

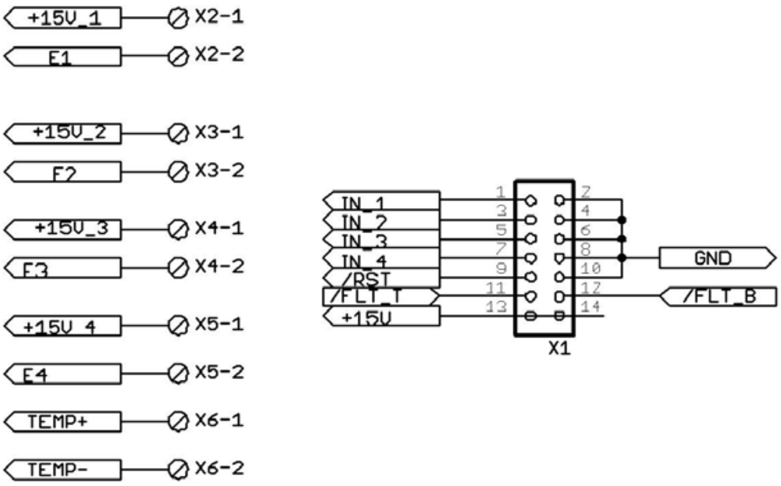

Figure 18 Power and Logic connectors

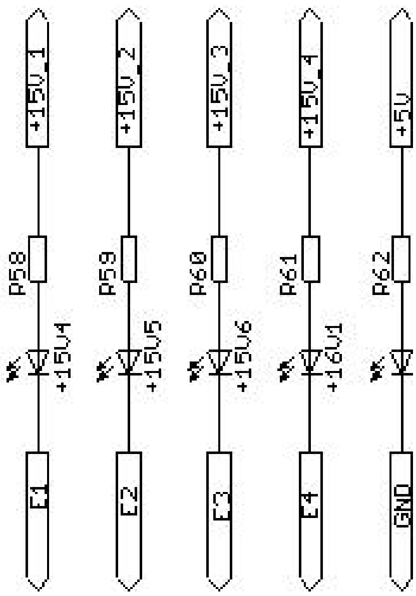

Figure 19 Logic signals

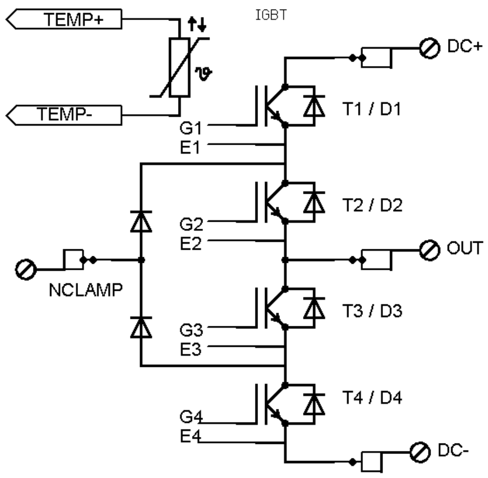

Figure 20 IGBT module

4.2 Layout

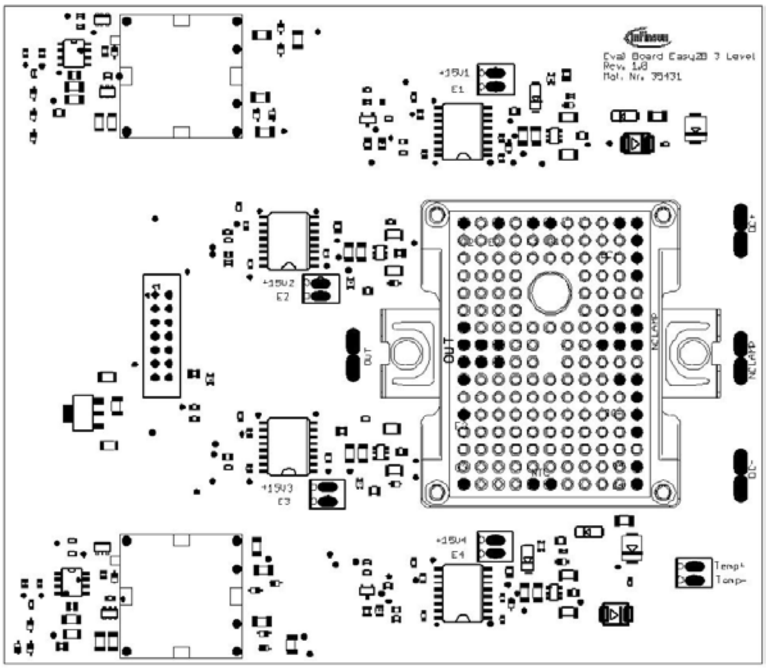

Figure 21 Assembly drawing

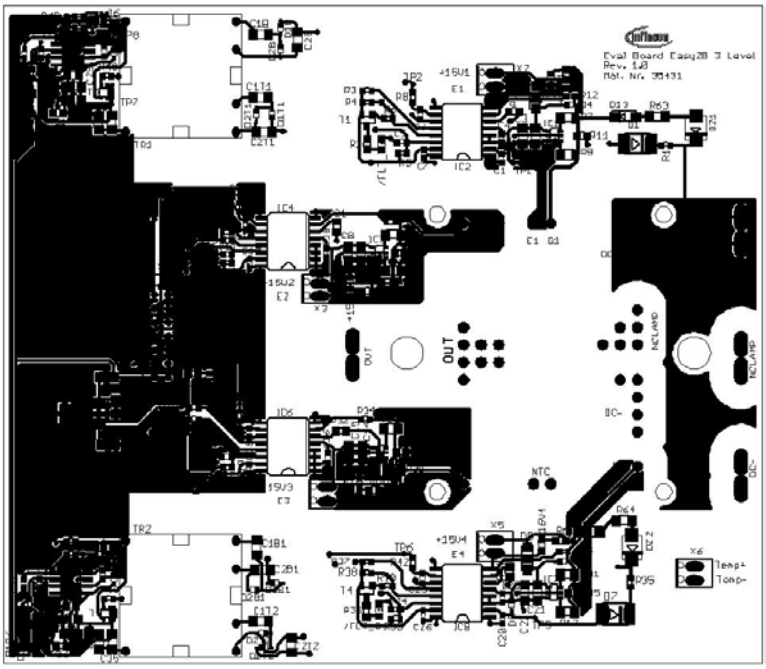

Figure 22 Top-Layer

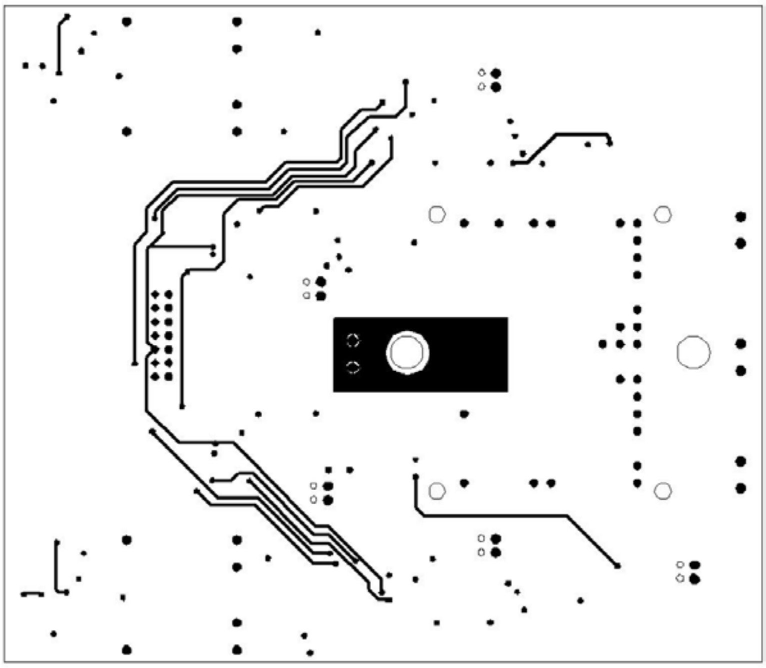

Figure 23 Layer-1

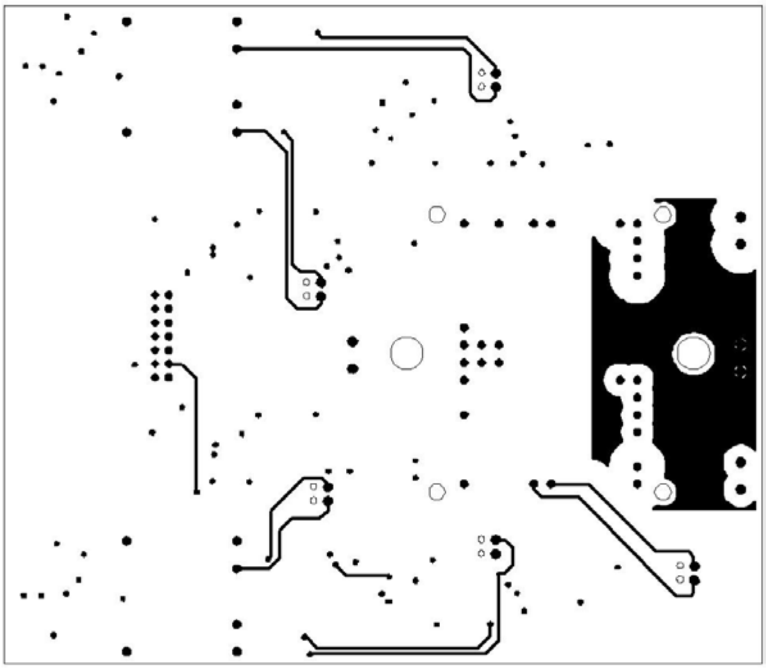

Figure 24 Layer-2

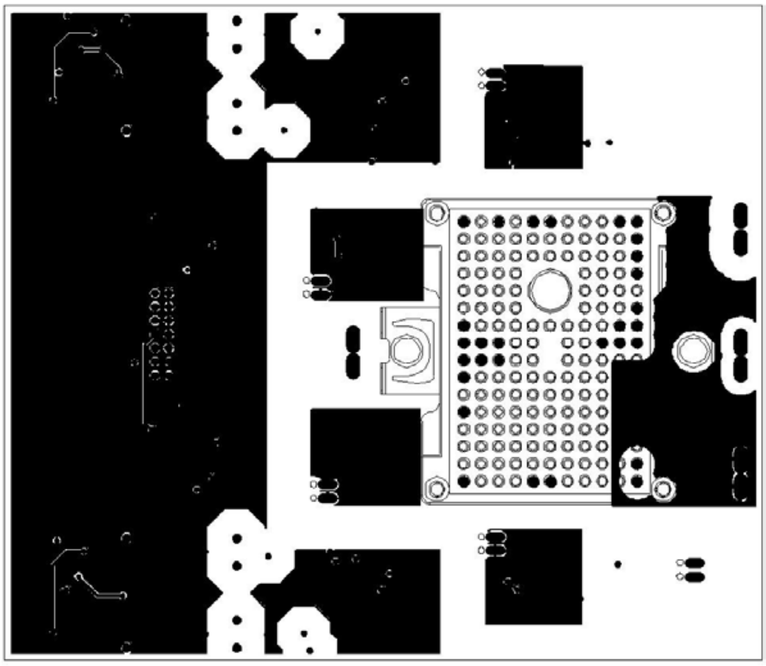

Figure 25 Bottom-Layer

5 Bill of Material of F3L030E07-F-W2_EVAL

The bill of material includes a part list as well as assembly notes.

The tolerances for resistors should be less or equal to ±1 %, for capacitors of the type C0G less or equal to ±5 % and for capacitors of the type X7R less or equal to ±10 %.

Type	Value / Type	Package	QTY	Name Part	Recommended Manufacturer
resistor	1k	R0603	3	R1, R35, R62	-
resistor	2k	R0805	4	R58, R59, R60, R61	-
resistor	39R	R0805	2	R2, R36	-
resistor	4k7	R0603	12	R3, R4, R5, R14, R15, R16, R25, R26, R27, R37, R38, R39	-
resistor	10k	R0603	6	R6, R11, R22, R33, R40, R45	-
resistor	0R47	R1206	4	R9, R20, R31, R43	Special pulse resistors
resistor	3R3	R1206	8	R7, R9, R18, R20, R29, R31, R41, R43	Special pulse resistors
resistor	68R1	R0603	4	R8, R19, R30, R42	-
resistor	10R	R0805	4	R110, R21, R32, R44	-
resistor	0R0	R0603	4	R12, R23, R34, R46	-
resistor	15R	R0603	2	R48, R49	-
resistor	68k	R0603	2	R47, R52	-
resistor	2k2	R0603	2	R50, R55	-
resistor	0R15	R0805	2	R51, R56	-
resistor	15R	R0603	2	R53, R54	-
resistor	150R	R1206	1	R57	-
resistor	10R	R1206	2	R63, R64	-
capacitor	4µ7/25V/X7R	C1206	26	C1B, C1B1, C1T1, C1T2, C2, C2B, C2B1, C2T1, C2T2, C3, C8, C9 , C14, C15, C21, C22, C27, C30, C32, C34, C35, C38, C40, C42, C43, C44	Murata
capacitor	100n/50V/X7R	C0603	10	C4, C7, C10, C13, C16, C19, C23, C26, C28, C36	Murata
capacitor	1µ/25V/X7R	C0805	2	C29, C37	Murata
capacitor	100p/50V/C0G	C0603	14	C1, C5, C6, C11, C12, C17, C181, C20, C24, C25,	Murata

				C31, C33 , C39, C41	
connector	MPT 0,5/ 2-2,54	MPT 0,5/ 2-2,54	5	X2, X3, X4, X5, X6	Phoenix contact
connector	163468844	16346884	1	X1	Tyco
mounting tabs for PCB	3866G68	3866G68	4	DC+, DC-, NCLAMP, OUT	Vogt
semiconductor	BC856	SOT23	2	T1, T4	-
semiconductor	ES1D	DO214AC	4	D3, D9, D13, D14	Vishay
semiconductor	BAT165	SOD323R	22	D1B, D1B1, D1R1, D1R2, D1R3, D1R4, D1R5, D1R6, D1T1, D1T2, D2, D2B, D2B1, D2T1, D2T2, D4, D5, D6, D8, D10, D11, D12,	Infineon
semiconductor	P6SMB480C	SMB	2	DZ1, DZ2	Diotec
semiconductor	ZXGD3004E6	SOT23-6	4	IC1, IC3, IC5, IC7	Zetex
semiconductor	1ED020I12-F	P-DSO-16	4	IC2, IC4, IC6, IC8	Infineon
semiconductor	STTH112U	SOD6	2	D1, D7	ST
semiconductor	IR2085S	SO08	2	IC9, IC10	International Rectifier
semiconductor	BSL302SN	TSOP-6	4	T5, T6, T7, T8	Infineon
semiconductor	ZSR500G	SOT223	1	U1	Zetex
semiconductor	F3L150R07W2E3_B11	Easy2B	1	IGBT	Infineon
semiconductor	LEDCHIPLED_GREEN	0805	5	+5V, +15V1, +15V2, +15V3, +16V4	-
semiconductor	LEDCHIPLED_RED	0805	2	/FLT_T, /FLT_B	-
transformer	T60403 D4615-X054		2	TR1, TR2	VAC

6 How to order the Evaluation Driver Boards

Every Evaluation Driver Board has its own IFX order number and can be ordered via your Infineon Sales Partner.

Information can also be found at the Infineons Web Page: www.infineon.com

CAD-data for the board described here are available on request. The use of this data is subjected to the disclaimer given in this AN. Please contact: WAR-IGBT-Application@infineon.com

IFX order number for F3L030E07-F-W2_EVAL: 35431

7 References

[1] Zhang Xi, Uwe Jansen, Holger Rüthing : 'IGBT power modules utilizing new 650V IGBT3 and Emitter Controlled Diode3 chips for 3-Level converter' ISBN: 978-3-8007-3158-9 Proceedings PCIM Europe 2009 Conference

[2] The AN2009-10 : 'Using the NTC inside a power electronic module', is available on Infineon website

[3] Bäßler, M., Ciliox A., Kanschat P : On the loss – softness trade-off: Are different chip versions needed for softness improvement" ISBN: 978-3-8007-3158-9 Proceedings PCIM Europe 2009 Conference

[4] AN2006-01 "Driving IGBTs with unipolar gate voltage"