

AN2012-08 Evaluation Adapter Board for 62mm Half Bridge IGBT Modules

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AN 2012-08

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

1 Introduction

The MA070E12/17_EVAL module adapter board, shown in Figure 1, offers reliable connection between driver and 62mm IGBT modules. Handling of the 62mm modules are described in [7] and [8]. The MA070E12/17_EVAL board is designed to work with all 62mm half bridge IGBT module types respectively in 1200V and 1700V classes. The MA070E12/17_EVAL adapter board is appropriate to be used in combination with the flexible driver Kit 2ED300E17-SFO evaluation adapter board and 2ED300C17-S /-ST EiceDRIVER™, both in single as well as in parallel configuration. The flexible driver kit allows for a paralleling of up to three IGBT modules. Each IGBT module within the parallel configuration needs one MA070E12/17_EVAL board as depicted in Figure 1.

The board is available from Infineon in small quantities. The properties of this board are described in the design feature chapter of this document, whereas the remaining paragraphs provide information to enable the customers to copy, modify and qualify the design for production, according to their own specific requirements.

Environmental conditions were considered in the design of the MA070E12/17_EVAL. Components qualified for a lead-free reflow soldering process were selected. The design was tested as described in this document but not qualified regarding manufacturing and operation within the whole operating temperature range or lifetime.

The boards provided by Infineon are subject to functional testing only.

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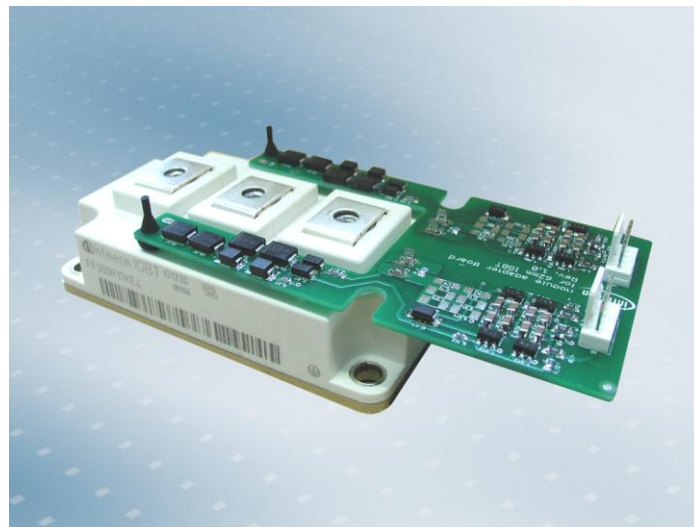
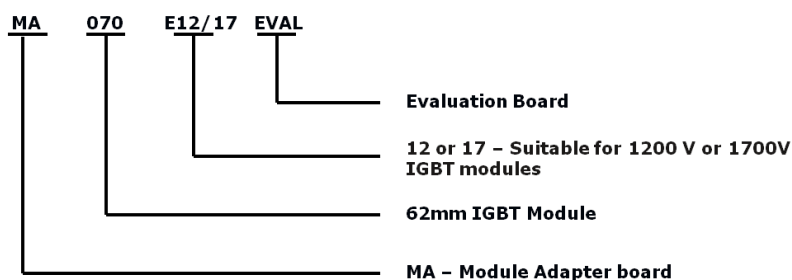


Figure 1: 62mm IGBT module FF300R17KE3 equipped with MA070E12/17_EVAL Evaluation Adapter board

1.1 Part Number explanation

Part number explanation:



2 Design features

Electrical features of the evaluation board as well as mechanical dimensions including necessary interface connections are presented in the following sections.

2.1 Main features

The MA070E12/17 module adapter board offers:

- Dual channel IGBT driver in combination with 2ED300E17-SFO [5] and 2ED300C17-S /-ST EiceDRIVER™
- Electrically and mechanically suitable for 62mm IGBT module family
- Different gate resistor values for turning-on and -off are possible
- IGBTs are secured against temporary collector - emitter overvoltages during turn-off by Active Clamping
- Desaturation output signals for short circuit monitoring
- All components, except connectors, are surface mounted devices with lead-free 260°C soldering profile
- The PCB is designed to fulfil the requirements of IEC61800-5-1, pollution degree 2, overvoltage category III

Useful features in case the MA070E12/17_EVAL is not used with 2ED300E17-SFO adapter board and 2ED300C17-S /-ST EiceDRIVER™:

- Can be used with max. $\pm 20\text{V}$ isolated power supply. Due to IGBT short circuit performance a value of max. +16V is suggested.
- Asymmetric power supply is also allowed, e.g. +16 V and -8 V
- Input PWM positive and negative voltage pulse level should be selected according to the actual power supply voltage level. Maximum +16 V and minimum -8 V at +16 V / -8 V power supply or maximum +15 V and minimum -15 V at +15 V / -15 V power supply.

2.2 Key Data

General key data and characteristic values are given in Table 1. These are typical values, measured at an ambient temperature of $T_{\text{amb}} = 25\text{ °C}$.

Table 1: Electrical Parameters

Parameter	Description	Value	Unit
U_{DC}	max. DC voltage supply	± 20	V
I_{G}	maximum output continuous current	± 8	A
$P_{\text{DC/DC}}$	max DC/DC output power per channel ¹	4	W
T_{op}	operating temperature ²	-40...+85	°C
T_{sto}	storage temperature	-40...+85	°C

¹ Only if MA070E12/17_EVAL is used in combination with 2ED300E17-SFO adapter board and 2ED300C17-S EiceDRIVER™

² Max. tolerable ambient temperature strictly depends on MA070E12/17_EVAL load conditions.

2.3 Mechanical dimensions

The dimensions of the MA070E12/17 evaluation board are given in Figure 2.

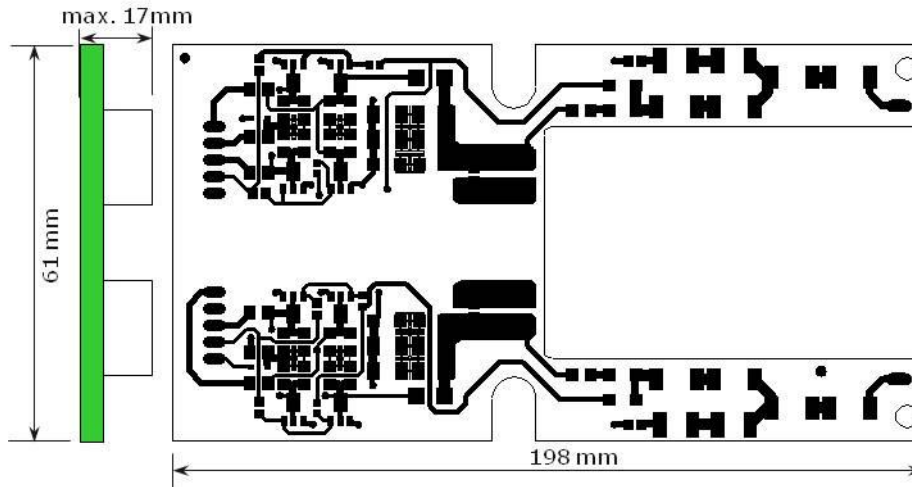


Figure 2: Mechanical dimension of MA070E12/17_EVAL

2.4 Pin assignment

After the module adapter has been mounted to the 62mm module, all external electrical signals listed in Table 2 should be applied to connector X1 and X2 as shown in Figure 3. If the MA070E12/17_EVAL is used in combination with the 2ED300E17-SFO, the necessary connections to the module adapter board are also depicted in Figure 3. In this case, the Sense-Signal of the 2ED300S17-S driver is used instead of the Out-Signal, making the internal booster of the 2ED300C17 redundant. The control signals required for module driving should be connected to the input interface of the 2ED300E17-SFO as described in AN2007-05.

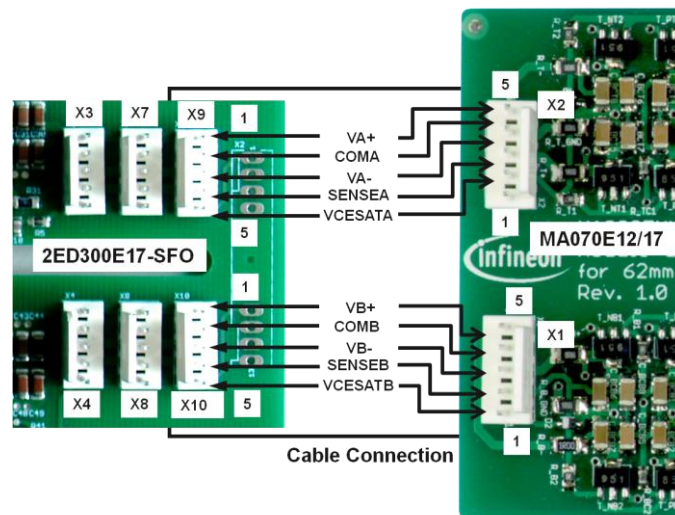


Figure 3: Connection between 2ED300E17-SFO and MA070E12/17

Table 2: Pin assignment of the connectors X1 and X2 MA070E12/17_EVAL

Pin	Label	Function	
X2.5	VA+	Insulated DC/DC positive voltage supply	high side
X2.4	COM A	Auxiliary emitter	
X2.3	VA-	Insulated DC/DC negative voltage supply	
X2.2	VGE A	Gate-emitter signal source	
X2.1	VCESATA	Desaturation voltage monitoring output	
X1.5	VB+	Insulated DC/DC positive voltage supply	low side
X1.4	COM B	Auxiliary emitter	
X1.3	VB-	Insulated DC/DC negative voltage supply	
X1.2	VGE B	Gate-emitter signal source	
X1.1	VCESATB	Desaturation voltage monitoring output	

3 Functionality on board

The MA070E12/17_EVAL basically supports already existing IGBT drivers in half-bridge configuration and provides additional functions separately for high- and low-side IGBT:

- Gate signal amplifier / emitter follower - booster
- V_{CE} monitoring for short circuit detection
- Active voltage clamping

Figure 4 depicts the MA070E12/17_EVAL with functional blocks and shows their physical location.

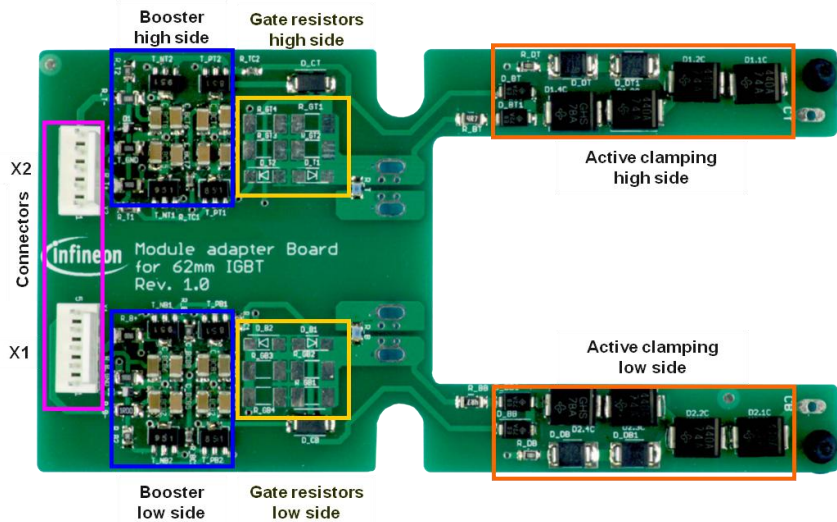


Figure 4: Functional blocks of the MA070E12/17_EVAL

3.1 Gate resistors

The MA070E12/17_EVAL are assembled and delivered as shown on Figure 4, but without gate resistors. Proper gate resistors should be soldered by the customer according to the chosen module. The datasheet value of the gate resistor according to the selected module may be used as a starting point, but lower values are permissible as long as the datasheet value of di_C/dt is not exceeded and the module is able to switch without oscillations. The switching losses will also vary with application parameters. For more information on these topics please refer to [1] and [2].

To avoid degradation of the gate resistors, repetitive pulse power rated resistors should be selected.

Further hints about the selection of pulse resistors are available on the web site of the manufacturers.

If it is intended to use different values for R_{gon} and R_{goff} assembly of the diodes D_T1, D_T2, D_B1, D_B2 is mandatory. In Figure 5, the locations of these diodes are shown. R_{gon} and R_{goff} are the equivalent turn-on and turn-off resistors for the paralleling of R_GT3 and R_GT4 respectively R_GT1 and R_GT2 as can be seen in Figure 11.

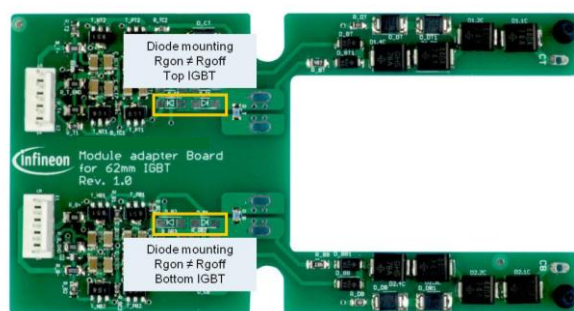


Figure 5: The MA070E12/17_EVAL location of optional diodes

Dead time has to be adjusted according to the chosen module, driver supply voltages and gate resistors. For details refer to [3].

3.2 Gate signal amplifier

During the turn-on and turn-off of the IGBT, a high peak of gate current must be delivered from the driver. Usually there is no technical problem when one module is driven. If one IGBT driver is used for modules connected in parallel, the signal amplifier must deliver the cumulated gate current. This setup suffers from multiple drawbacks as described in [4] and [5]. To overcome the limitations of the single driver approach in paralleling, each IGBT module should be equipped with one adapter board. The use of MA070E12/17_EVAL boards offers a dedicated solution to fulfill the high peak current demand of each paralleled IGBT module. In this approach all modules are controlled by one PWM input signal, but driven by a proper adequate power source, also eliminating circulation current among paralleled modules.

3.3 V_{CE} monitoring for short circuit detection

When the IGBT conducts a current several times higher than the nominal current, the IGBT desaturates and the collector-emitter voltage increases. This behaviour can be practically used for short circuit detection and protection of the IGBT. The short circuit duration time for Infineon 1200V and 1700V IGBT modules must not exceed 10 μ s. During this time the short circuit should be detected and the IGBT switched off without exceeding V_{CES} .

If the MA070E12/17_EVAL board is used in combination with 2ED300E17-SFO, the soft shut down resistors R_{SSD} must be chosen correctly in order to ensure proper short circuit protection. Chapter 3.5 of AN2007-05 describes the procedure in detail.

3.4 Active voltage clamping – boosted version

Active clamping is a technique which keeps transient overvoltages below the critical limits when the IGBT turns off. The standard approach for active clamping is to use a chain of avalanche diodes connected between the auxiliary collector and the gate of an IGBT module. When the collector-emitter voltage exceeds the diodes breakdown voltage, the diodes current sums up with the current from the driver output. Due to the now increased gate-emitter voltage the transistor is held in an active mode and the turning-off process is interrupted. The di_c/dt slows down which results in a limited voltage overshoot. Avalanche diodes conduct high peak currents during the time period in which the clamping is actively limiting the overvoltage.

Overvoltage protection of the MA070E12/17_EVAL is based on active clamping as described above. The clamping diodes are connected directly to the IGBT's gate as well as to the input of the amplifier located on the MA070E12/17_EVAL. Therefore, the major amount of current for recharging the gate is derived from the gate driver's power supply instead of via the clamping diodes. This technique offers the advantage to use TVS diodes with lower pulse power. The two versions of the evaluation adapter boards for 1200V and 1700V are sharing the same layout. The difference between both is the choice of the TVS diodes for each voltage class.

Active clamping is intended as a means of overvoltage protection in case of an over-current and short-circuit turn-off. If active clamping operates repetitively, e.g. because of extraordinary high DC-link stray inductance or excessive DC-link voltage, a significant increase in switching losses might damage the module.

3.5 Maximum switching frequency

The switching frequency of the adapter board is limited either by the maximum output power of the driver power supply or by the maximum temperature of the PCB due to the power losses in the external gate resistors. These power losses in the gate resistors depend on the IGBT gate charge, gate voltage magnitude and on the switching frequency of the IGBT. Due to the power losses in the external gate resistors, heat will be generated, which leads to an increase of the PCB temperature in the neighborhood of these resistors. This temperature must not be higher than the maximum working temperature of the PCB, i.e. 105°C for a standard FR4 material.

The calculation of the power losses in the gate resistors can be done by utilizing equation (1):

$$P_{dis} = P(R_{EXT}) + P(R_{INT}) = \Delta V_{out} \cdot f_s \cdot Q_G \quad (1)$$

where:

P_{dis} = dissipated power

$P(R_{EXT})$ = dissipated power of the external gate resistors

$P(R_{INT})$ = dissipated power of the IGBT module internal gate resistor

ΔV_{out} = voltage magnitude at the driver output

f_s = switching frequency

Q_G = IGBT gate charge for the given gate voltage range

The ratio of the losses dissipated internally $P(R_{INT})$ and externally $P(R_{EXT})$ corresponds directly to the ratio of the mentioned R_{INT} and R_{EXT} resistors.

Due to the PCB temperature criteria, the power dissipated in the external gate resistors $P(R_{EXT})$ has to be considered for the thermal design.

Figure 6 illustrates the PCB board temperature around the gate resistors depending on the switching frequency and defined conditions: $T_{amb} = 60^{\circ}\text{C}$, $V_{GE} = -15\text{V}/+15\text{V}$. Used at a switching frequency of 20kHz, the board temperature remains clearly below the critical limit of 105°C for a standard FR4 PCB material.

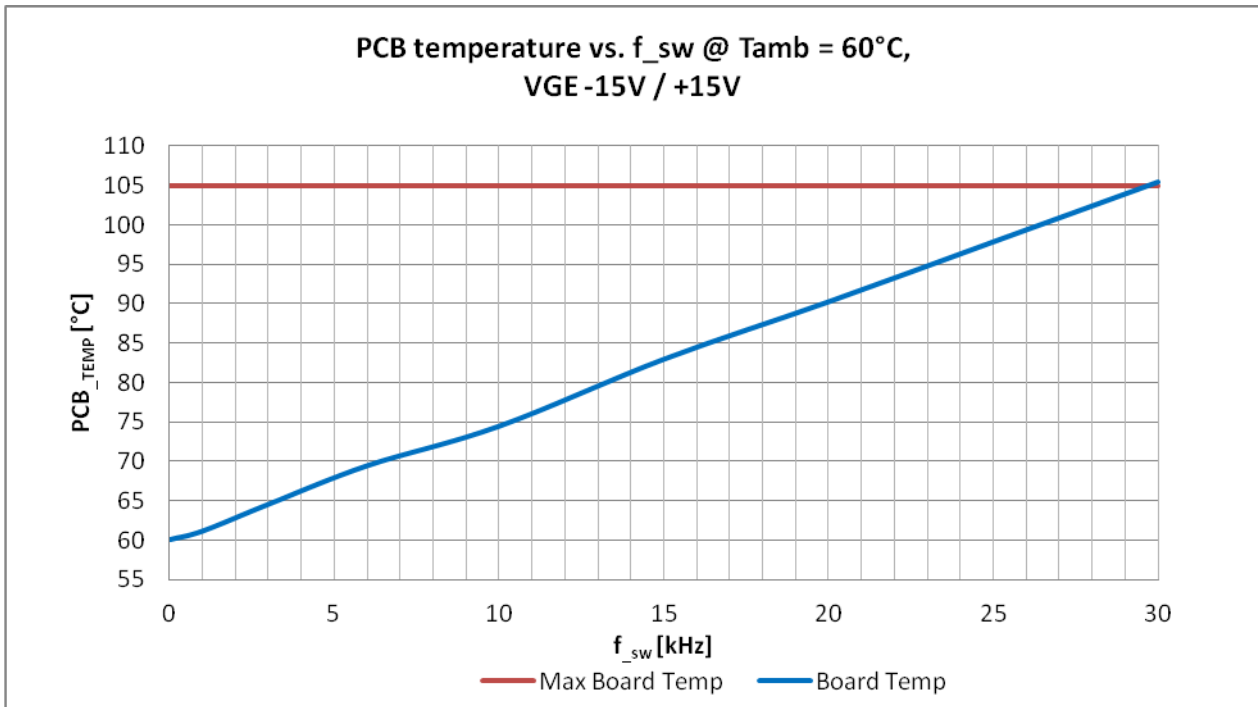


Figure 6: board temperature around the gate resistors of MA070E12/17_EVAL board in conjunction with FF300R17KE4 IGBT module

4 Paralleling

In contrast to the operation of one single IGBT, the switching of paralleled IGBT modules on the same operation point is not trivial. This can be explained by the fact that the IGBTs have a certain variation in their characteristics. A direct consequence of this is a slight current imbalance between the IGBTs. The biggest challenge is to minimize the deviation of the leg current to achieve highly efficient systems and an improved reliability.

Two main factors have a dominant role in the current maldistribution:

- the difference between the impedance of each leg of the paralleled setup
- the difference in the output voltages of the individual leg of the paralleled setup

4.1 Static current imbalance

The static current imbalance can be caused by the variation of

- the collector-emitter voltage of each leg of the paralleled setup
- the resistance of the main current path

4.2 Dynamic current imbalance

The dynamic current imbalance can be caused by the variation of

- the transmission characteristics caused by the different V_{GEth} of each IGBT
- the impedance of the main current path
- the stray inductance of the internal and external commutation path of the IGBT module
- the IGBT driver output resistance in the paralleled legs
- the transfer characteristic $I_C = f(V_{GE})$

4.3 Paralleling with MA070E12/17_EVAL

The MA070E12/17_EVAL was primarily designed to work with the evaluation driver board 2ED300E17-SFO_EVAL which allows the parallel connection of up to three modules as represented in Figure 7. It must be noticed that soft shut down resistors R_{SSD} in every case should be selected according to AN2007-05 chapter 3.5.

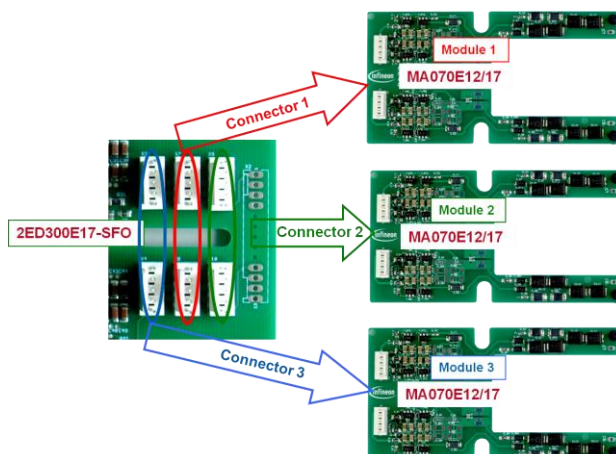


Figure 7: Principle of parallel connection of 3 MA070E12/17_EVAL with 2ED300E17-SFO_Eval

The wires to connect the driver to the adapter boards should have the same length to avoid differences in signal run time between the gates of the three legs. Star connection of the IGBTs reduces the cross flow in the auxiliary emitter paths during the switching sequence. The MA070E12/17_EVAL board is equipped with 4R7 resistors in the auxiliary emitter path and -15V/+15V power supply lines to reduce the current cross flow between the units of the paralleled circuits. Figure 8 shows the switching behavior of three FF300R17KE4 modules in parallel, driven by 2ED300E17-SFO_Eval and 2ED300C17-S /-ST EiceDRIVER™.

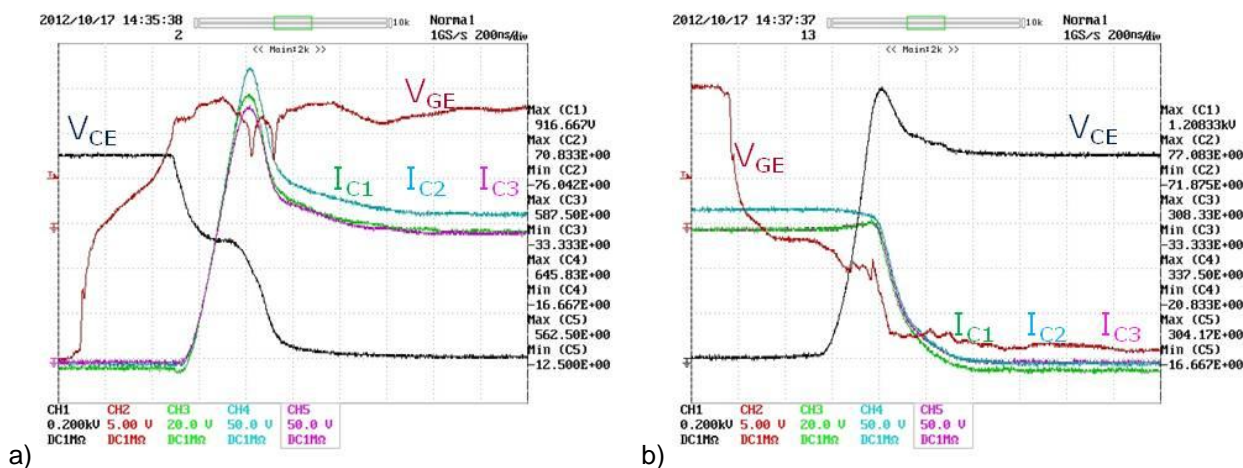


Figure 8: Current distribution on the AC terminals of 3 parallel FF300R17KE4 modules
a) Turn-on
b) Turn-off

The turn-on and turn-off were measured with a gate resistance $R_{gon} = R_{goff} = 1R5$ and at $T_{amb} = 25^{\circ}C$.

5 Schematics and Layouts

To meet individual customer requirements and make the evaluation adapter board for the 62mm IGBT module a basis for development or modification, all necessary technical data like schematic, layout and components are included in this chapter.

5.1 Schematics

Figure 9 depicts the driver circuit of the high side IGBT.

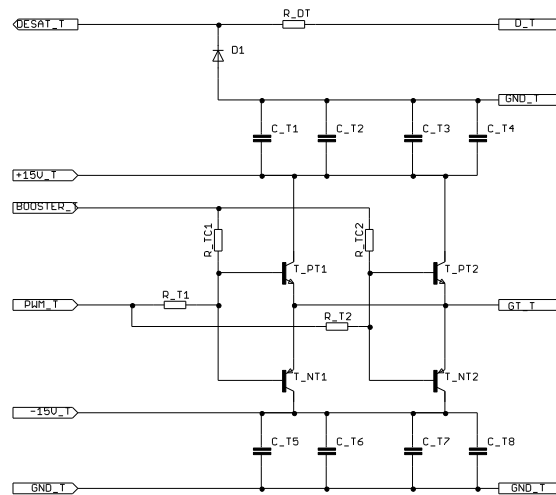


Figure 9: MA070E12/17_EVAL booster high side

Figure 10 illustrates the driver circuit of the low side IGBT.

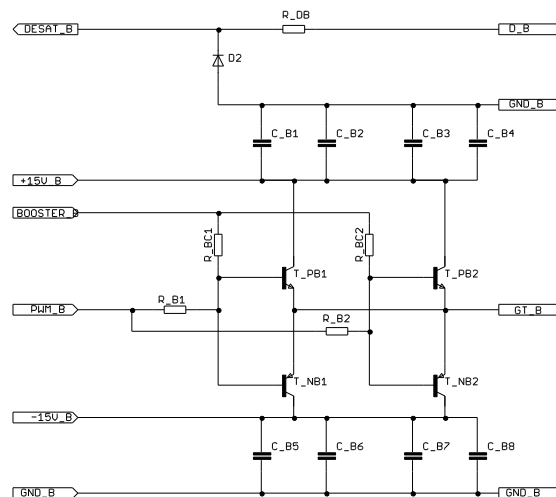


Figure 10: MA070E12/17_EVAL booster low side

Figure 11 shows the gate resistors and active clamping circuit of high and low side IGBTs.

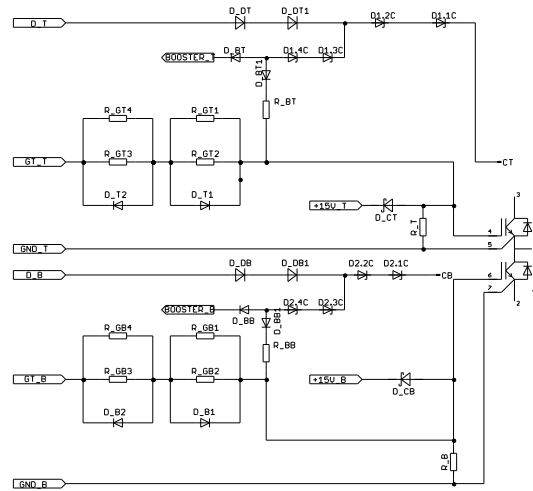


Figure 11: MA070E12/17_EVAL gate resistor and active clamping high and low side

Figure 12 details the pin assignment of the high and low side of MA070E12/17_EVAL's connectors.

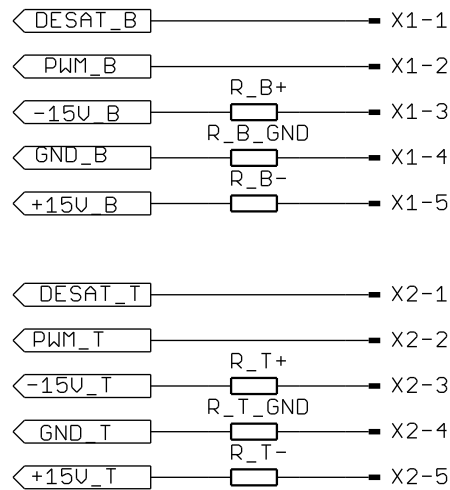


Figure 12: MA070E12/17_EVAL connectors

6 Bill of Material

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

The tolerances for resistors should be less or equal to $\pm 1\%$, for capacitors of the type COG less or equal to $\pm 5\%$ and for capacitors of the type X7R less or equal to $\pm 10\%$.

The basic circuit and layout for MA070E12 and MA070E17 are all the same. The only difference is the type of transil diodes used for active clamping as can be seen in the bill of materials. Gate resistors should be assembled according to the hints given in Table 3.

Table 3: Assembly Active clamping diodes on the MA070E12/17_EVAL board

Board Names	Assembled diodes	Types of assembled diodes
MA070E12_EVAL	D1.1C, D1.2C, D1.3C, D1.4C D2.1C, D2.2C, D2.3C, D2.4C	SMJC188A
MA070E17_EVAL	D1.1C, D1.2C, D1.3C D2.1C, D2.2C, D2.3C (D1.4C and D2.4C are bypassed by 0R resistors or wire)	1.5SMC440A

Table 4: Bill of Material for MA070E12_EVAL adapter board

Type	Value / Type	Package	QTY	Name Part	Recommended Manufacturer	Assembly
Resistor	12R	R0805	4	R_B1, R_B2, R_T1, R_T2,	no special	yes
Resistor	1k	R0805	2	R_DB, RD_T	no special	yes
Resistor	4R7	M1206	6	R_B+, R_B-, R_T+, R_T-, R_B_GND, R_T_GND	no special	yes
Resistor	12R	R0603	4	R_BC1, R_BC2, R_TC1, R_TC2	no special	yes
Resistor	10k	R0805	2	R_T, R_B	no special	yes
Semiconductor	BAT165	SOD323	2	D1, D2	Infineon	yes
Semiconductor	STPS1L40	SMB	2	D1, D2	STM	yes
Semiconductor	ES1D	DO214AC	8	D_B1, D_B2, D_BB, D_BB1, D_T1, D_T2, D_BT, D_BT1	Vishay	yes
Semiconductor	1.5SMC188 A	SMC	8	D1.1C, D1.2C, D1.3C, D1.4C D2.1C, D2.2C, D2.3C, D2.4C	Vishay	yes
Semiconductor	STTH112U	SOD6	4	D_DB, D_DB1, D_DT, D_DT1	STM	yes
Resistor	1R	R1206	2	R_BB, R_BT	no special	yes
R esistor*	variable	R2010	8	R_GB1, R_GB2, R_GB3, R_GB4, R_GT1, R_GT2, R_GT3, R_GT4	special pulse resistor	No
Connector	ST2.8	AMP 0-0735187-2	2	CB, CT	TE-connectivity	yes
Semiconductor	ZXTN2010Z	SOT89	4	T_PT1, T_PT2, T_PB1, T_PB2,	Zetex	yes

Type	Value / Type	Package	QTY	Name Part	Recommended Manufacturer	Assembly
Semiconductor	ZXTP2012Z	SOT89	4	T_NT1, T_NT2, T_NB1, T_NB2	Zetex	yes
Connector	6410-5A	6410-5A	2	X1, X2	Molex	yes
Capacitor	4 μ 7	C1206	16	C_B1, C_B2, C_B3, C_B4, C_B5, C_B6, C_B7, C_B8, C_T1, C_T2, C_T3, C_T4, C_T5, C_T6, C_T7, C_T8,	Murata	yes
Resistor	12R	R0805	4	R_B1, R_B2, R_T1, R_T2	no special	yes
Resistor	1k	R0805	2	R_DB, RD_T	no special	yes

*Pulse power rated types

Table 5: Bill of Material for MA070E17_EVAL adapter board

Type	Value / Type	Package	QTY	Name Part	Recommended Manufacturer	Assembly
resistor	12R	R0805	4	R_B1, R_B2, R_T1, R_T2,	no special	yes
Resistor	1k	R0805	2	R_DB, RD_T	no special	yes
Resistor	4R7	M1206	6	R_B+, R_B-, R_T+, R_T-, R_B_GND, R_T_GND	no special	yes
Resistor	12R	R0603	4	R_BC1, R_BC2, R_TC1, R_TC2	no special	yes
Resistor	10k	R0805	2	R_T, R_B	no special	yes
Semiconductor	BAT165	SOD323	2	D1, D2	Infineon	yes
Semiconductor	STPS1L40	SMB	2	D1, D2	STM	yes
Semiconductor	ES1D	DO214AC	8	D_B1, D_B2, D_BB, D_BB1, D_T1, D_T2, D_BT, D_BT1	Vishay	yes
Semiconductor	1.5SMC440 A	SMC	6	D1.1C, D1.2C, D1.3C, D2.1C, D2.2C, D2.3C	Vishay	yes
Semiconductor	1.5SMC188 A	SMC	2	D1.4C, D2.4C	Vishay	bypassed by 0R resistor (i.e. 2512 Package)
Semiconductor	STTH112U	SOD6	4	D_DB, D_DB1, D_DT, D_DT1	STM	yes
Resistor	1R	R1206	2	R_BB, R_BT	no special	yes
Resistor*	variable	R2010	8	R_GB1, R_GB2, R_GB3, R_GB4, R_GT1, R_GT2, R_GT3, R_GT4	special pulse resistor	No
Connector	ST2.8	AMP 0-0735187-2	2	CB, CT	TE-connectivity	yes
Semiconductor	ZXTN2010Z	SOT89	4	T_PT1, T_PT2, T_PB1, T_PB2,	Zetex	yes
Semiconductor	ZXTP2012Z	SOT89	4	T_NT1, T_NT2, T_NB1, T_NB2	Zetex	yes

Type	Value / Type	Package	QTY	Name Part	Recommended Manufacturer	Assembly
Connector	6410-5A	6410-5A	2	X1, X2	Molex	yes
Capacitor	4 μ 7	C1206	16	C_B1, C_B2, C_B3, C_B4, C_B5, C_B6, C_B7, C_B8, C_T1, C_T2, C_T3, C_T4, C_T5, C_T6, C_T7, C_T8,	Murata	yes
Resistor	12R	R0805	4	R_B1, R_B2, R_T1, R_T2	no special	yes
Resistor	1k	R0805	2	R_DB, RD_T	no special	yes

*Pulse power rated types

7 How to order the Evaluation Adapter Board

Every evaluation board has its own IFX order number and can be ordered via your Infineon sales partner.

Information can also be found at the Infineon 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 MA070E12_EVAL:	SP001071992
IFX order number for MA070E17_EVAL:	SP001071998
IFX order number for 2ED300E17-SFO:	SP000355559
IFX order number for 2ED300C17-S:	SP000359184
IFX order number for 2ED300C17-ST:	SP000359188

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