

# MA400E12/17 and MA401E12/17 – Module Adapter Board for IHM IGBT Modules

## About this document

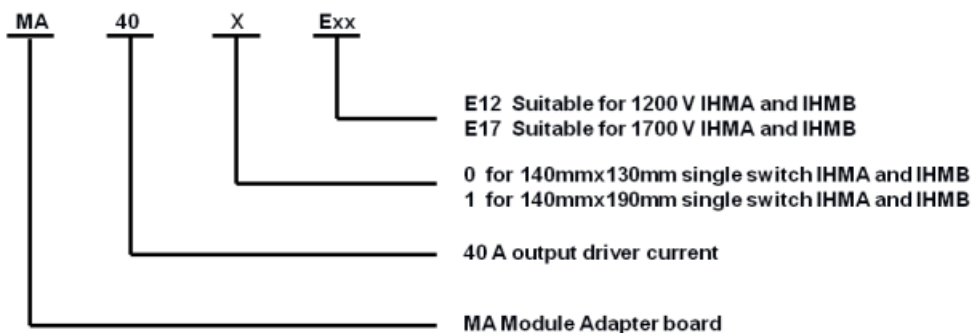
### Scope and purpose

The MA40xE12 and MA40xE17 evaluation adapter boards are developed for the driving of 1200V and 1700V single switch IHM modules

### Intended audience

The intended audiences for this document are design engineers, technicians, and developers of electronic systems.

#### Part number explanation:



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### Table of contents

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## Introduction

### 1 Introduction

The MA40xE12 and MA40xE17 evaluation adapter boards are developed for the driving of 1200V and 1700V single switch IHM modules with an integrated active booster and additionally short circuit protection feature to assure an easy and optimum functionality of the IGBT. Used in conjunction with the 2ED300E17-SFO evaluation adapter board and the 2ED300C17-S or -ST EiceDRIVER™ turns the adapter evaluation board into the Flexible driver Starter Kit displayed in Figure 1b. The Flexible Evaluation adapter board is dedicated to single module operation. In cases of IHM parallel switching, one 2ED300E17-SFO adapter board and one 2ED300C17-S driver is required for up to three modules paralleled, each equipped with one MA40xExx board.

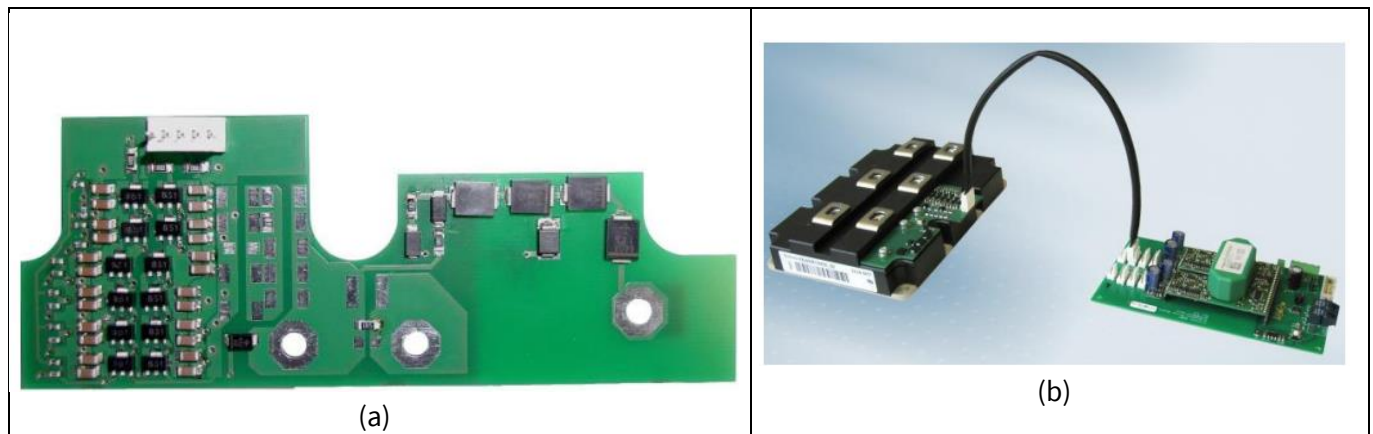
The MA40xExx module adapter boards are available from Infineon in small quantities. Functions and properties of these parts are described in the datasheet chapter of this document whereas the remaining paragraphs provide information intended to enable the customer to copy, modify and qualify the design for their own specific application.

Environmental conditions were considered in the design of the MA40xExx. The requirements for leadfree reflow soldering have been considered when components were selected. However the design was only tested as described in this document but not qualified regarding manufacturing and operation over the whole operating ambient temperature range or lifetime.

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 Withdraw (PWD) as regular products.

See Legal Disclaimer and Warnings for further restrictions on Infineon warranty and liability.



**Figure 1** a) Module Adapter board, MA400E12,

b) Driver Starter Kit for IHM module

**Design features**

## 2 Design features

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

### 2.1 Main features

The MA40xExx module adapter board offers the following features:

- Electrically and mechanically suitable for IHM modules family
- Design target for operating temperature: -55°C to 85°C
- Different gate resistor values for turning-on and -off are possible
- The IGBT is protected against temporary overvoltages during turn-off by Active Clamping
- Diodes for IGBT desaturation monitoring to handle short circuit conditions are implemented
- All components, except connectors, are surface mount devices (SMD) with lead free 260°C soldering profile
- PCB is designed to fulfill the requirements of IEC61800-5-1, pollution degree 2, overvoltage category III (creepage – 11mm)

If the MA40xExx is not used with the 2ED300E17-SFO adapter board and a 2ED300C17-S /-ST EiceDRIVER™ these additional features might be useful:

- Booster-Stage input resistance is 90  $\Omega$
- Can be used with max.  $\pm 20V$  isolated power supply. Due to IGBT short circuit performance a maximum value of VGE ~15V is recommended
- Asymmetric power supply is also allowed e.g. -8V and +15V
- Input PWM voltage level should be selected according to the power supply voltage level. If an asymmetrical supply voltage of -8V/+15V is applied, the PWM signal should not exceed +15V and should not be lower than -8V

## Design features

### 2.2 Key data

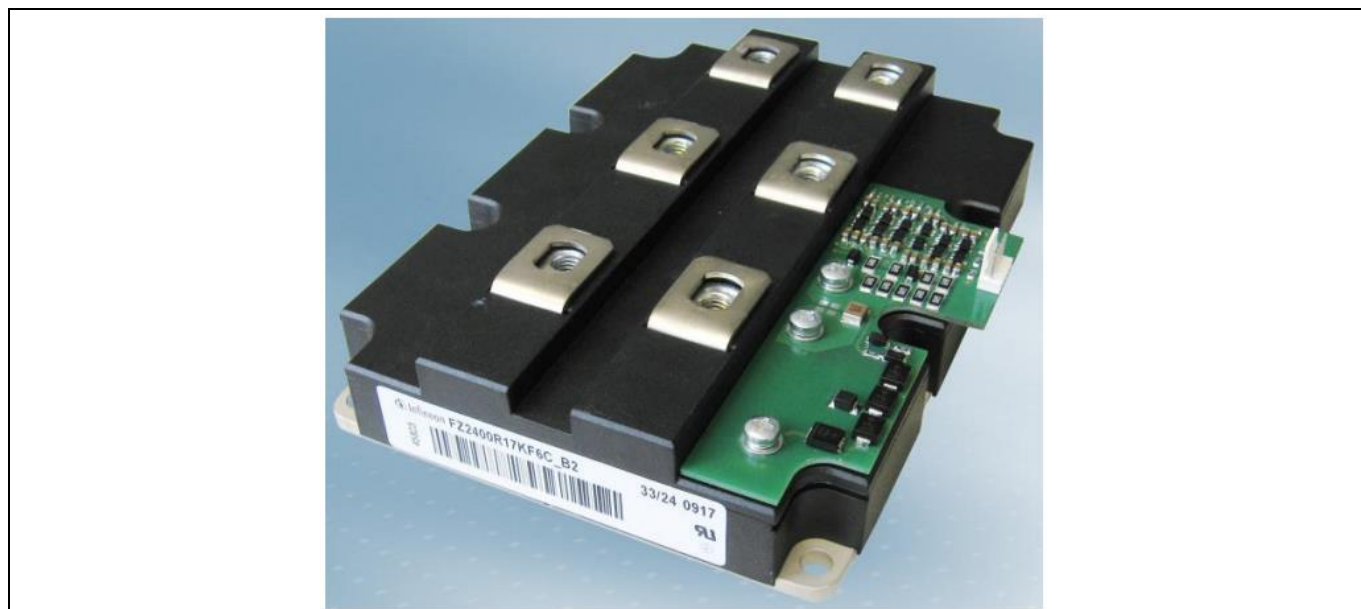
All values given in the table below are typical values, measured at an ambient temperature of  $T_A = 25\text{ °C}$ .

**Table 1 General key data and characteristic values**

Parameter	Description	Value	Unit
$V_{DC}$	maximum DC voltage supply	$\pm 20$	V
$I_G$	peak output current	$\pm 40$	A
$R_{Gmin}$	minimum gate resistor value when $V_{DC} = \pm 15\text{V}$ (internal module resistor $R_{INT}$ + external $R_{EXT}$ )	0.1	$\Omega$
$P_{DC/DC}$	max DC/DC output power per one channel <sup>1</sup>	4	W
$f_s$	maximum PWM signal frequency	60	kHz
$T_{op}$	operating temperature (design target) <sup>2</sup>	-55...+85	°C
$T_{sto}$	storage temperature (design target)	-55...+85	°C

### 2.3 Mechanical dimensions and mounting procedure

The MA40xExx should be screwed to the IHM auxiliary terminals according to AN2004-05<sup>3</sup>. In that way necessary connections between module adapter and module itself are done correctly as shown in Figure 2.



**Figure 2 The MA400E12 correctly mounted on an IHM module**

PCB outline and relevant dimensions needed for better system integration are shown in Figure 3.

<sup>1</sup> Only when MA400Exx is used together with 2ED300E17-SFO adapter board and 2ED300C17-S EiceDRIVER™

<sup>2</sup> Maximum ambient temperature strictly depends on MA40xExx load conditions.

<sup>3</sup> The [AN2004-05](#): 'Mounting process IHM modules' is available on the Infineon website.

## Design features



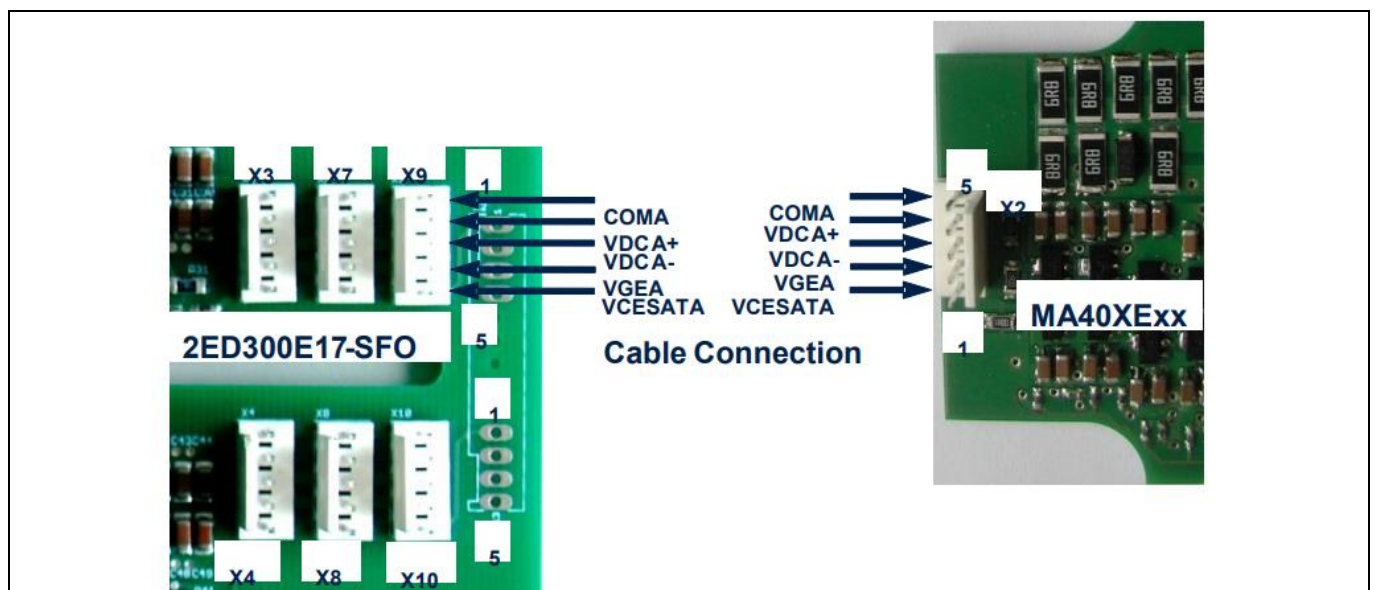
**Figure 3 Dimensions of the MA400E12/17 module adapter board**

The mechanical difference between MA400Exx and MA401Exx is the shifted position of the gate and emitter screw terminals according to the related IHM housing.

## 2.4 Pin assignment

After the module adapter has been correctly mounted to the IHM module, all external electrical control signals are to be applied to connector X2 as shown on Figure 4 and listed in Table 2.

If the MA40xExx is used in combination with the 2ED300E17-SFO, control signals required for module driving should be connected to the input Interface of the 2ED300E17-SFO as described within the [AN2007-05](#). In that way no additional connections between module and IGBT driver are needed.



**Design features****Figure 4** Connections between 2ED300E17-SFO and MA400Exx or MA401Exx**Table 2** The external electrical signals description of MA400Exx and MA401Exx

Pin	Label	Function
X2.1	VCESAT	Desaturation voltage monitoring output
X2.2	VGE	Gate-emitter signal source
X2.3	VDC-	Isolated DC/DC negative voltage supply
X2.4	COM	Auxiliary emitter and power supply ground
X2.5	VDC+	Isolated DC/DC positive voltage supply



## Electrical features

### 3 Electrical features

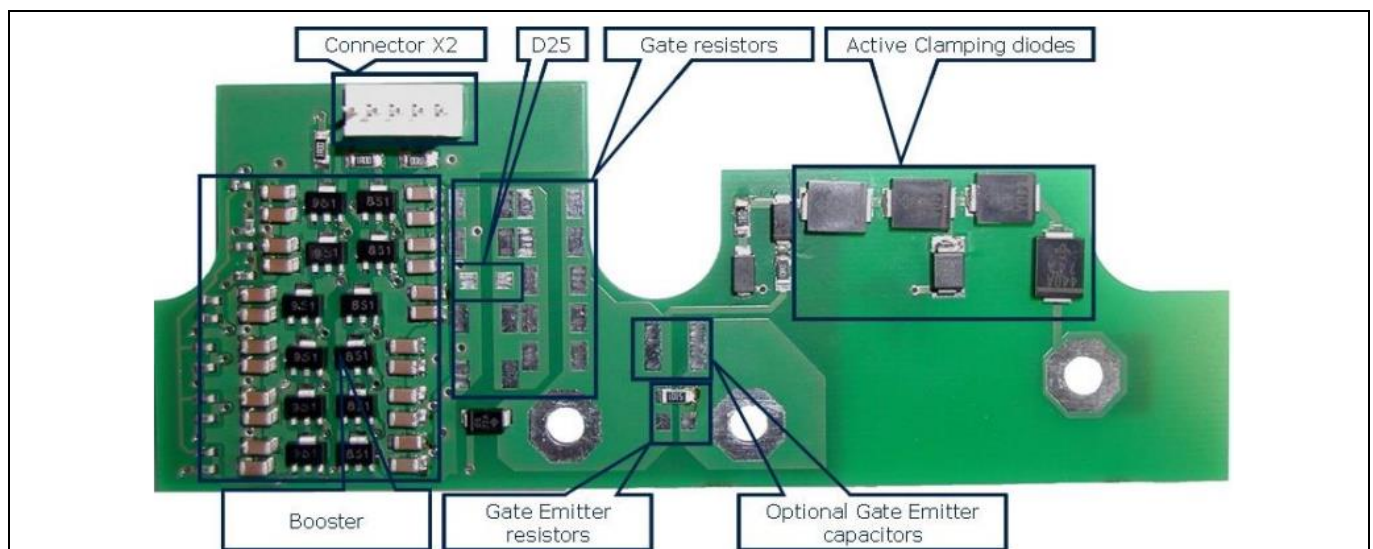
The following section describes details of the adapter boards related to their electrical features.

#### 3.1 Functionality on board

The MA400Exx or MA401Exx provide the following functions:

- Possibility to implement different gate resistors for turn-on and turn-off
- Bipolar booster stage with an output current of 40A
- VCE monitoring for short circuit detection
- Active clamping

Figure 5 below depicts the MA40xExx with the functions described above and shows their physical location.



**Figure 5 The MA40xExx with marked functions**

#### 3.2 Gate resistors

Any MA40xExx is assembled and delivered without gate resistors as shown on Figure 5. The correct gate resistors have to be soldered by the customer according to the IGBT module used.

In case the values of  $R_{Gon}$  and  $R_{Goff}$  need to be different, the Diode D25 needs to be assembled to separately adjust the values of  $R_{Gon}$  and  $R_{Goff}$ .



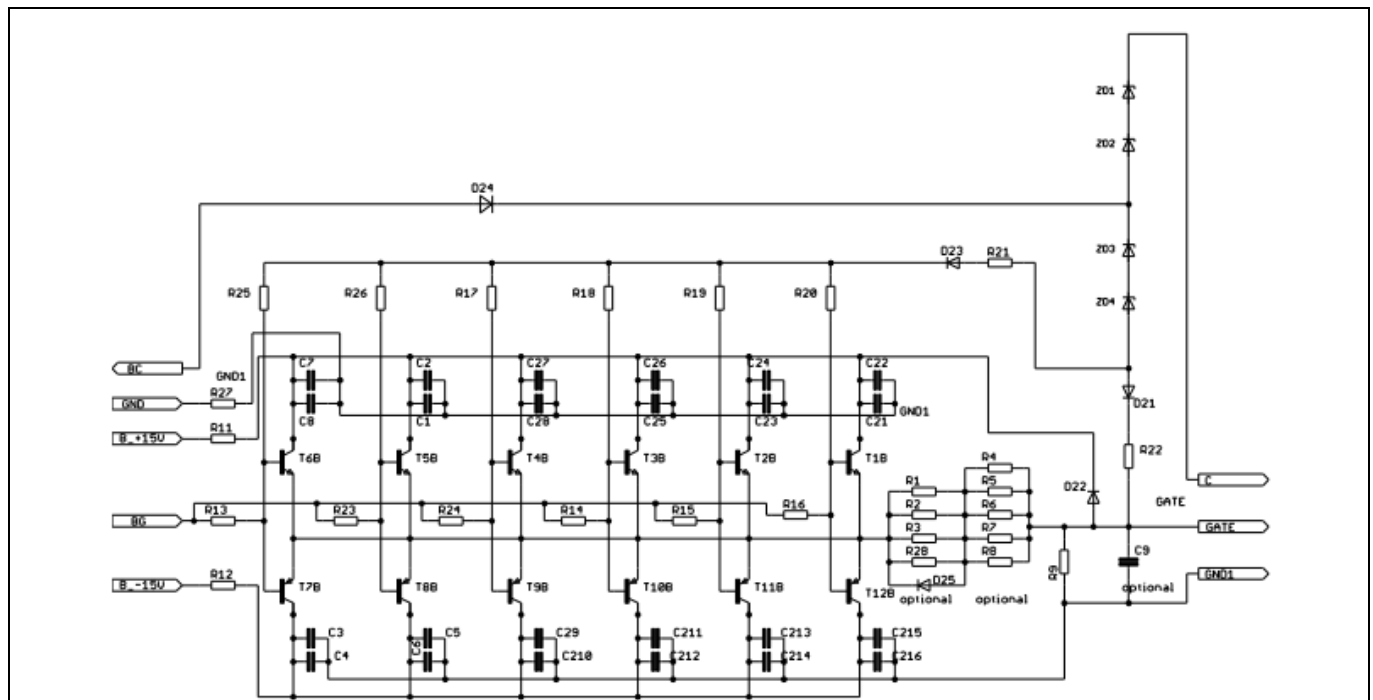
## Electrical features

### 3.3 Gate signal amplifier<sup>4</sup>

While the IGBT switches on or off, high peaks of the gate current have to be delivered from the driver. Usually there is no technical problem when driving a single module. If one IGBT driver is used for modules connected in parallel, the driver's amplifier has to provide the cumulated gate currents. This switching condition leads to the gate power loss being concentrated in one relatively small physical area and may result in thermal problems. The high peak currents also require a high current gain driver.

Overcoming gain limitation becomes possible when the module adapter includes a dedicated gate signal amplifier. The schematic in Figure 6 shows, that the MA40xExx has an emitter follower or booster stage already implemented. Thanks to six complementary bipolar transistors connected in parallel the minimum gain @ $I_G=40A$  is not smaller than 100 based on ZXTN2010Z and ZXTN2012Z bipolar transistors datasheets.

Having a booster stage comes with the benefit to get excellent control on the gate-emitter voltage of any IHM-type module and enables a simplified design in paralleling IGBT-modules.



**Figure 6** Booster stage of the MA40xExx

### 3.4 $V_{CE}$ monitoring for short circuit detection

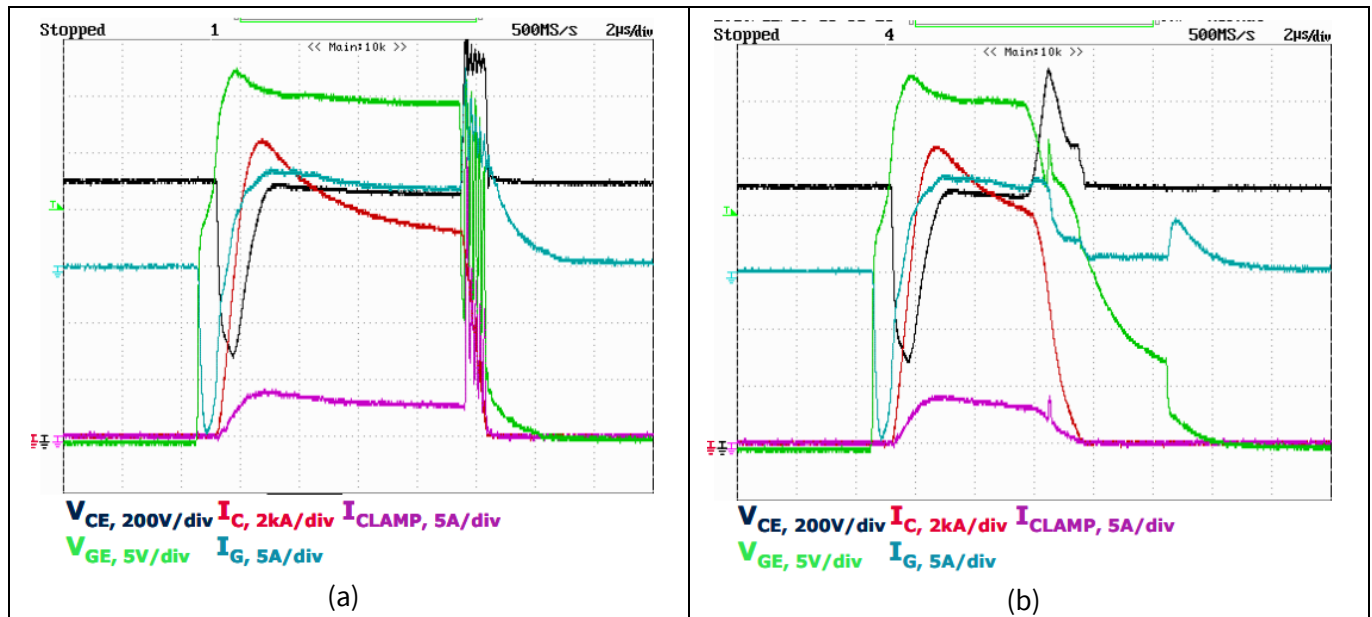
If the IGBT conducts a current a few times higher than the nominal value, the transistor desaturates and the voltage across the device increases. This behavior can be used for short circuit detection and turn-off of the IGBT. The short circuit needs to be detected and the IGBT has to be turned off without exceeding its maximum blocking voltage, within 10µs.

When the MA40xExx is connected to a 2ED300E17-SFO the RSSD resistors that define the Soft Shut Down function must be chosen correctly in order to ensure proper short circuit protection. The detailed procedure is described in [AN2007-05](#) chapter 3.5. Figure 7a shows the short circuit behavior of FZ1600R17HP4\_B2 IHMB

<sup>4</sup> More information can be found in EPE07 paper 'Benefits of System-oriented Module Design for High Power Inverters', or PELINCEC2005 paper 'Dynamic Voltage Rise Control – the Most Efficient Way to Control Turn-off Switching Behavior of IGBT Transistors'.

## Electrical features

modules where short circuit protection on the 2ED300E17-SFO was disabled. To protect the device from destruction in this test, the gate-pulse applied to turn on had a duration of 10 $\mu$ s. High  $di_C/dt$  during turn-off creates a large overvoltage spike which is limited by active clamping. Figure 7b depicts how soft shut-down with a properly selected RSSD limits the short circuit time to less than 10 $\mu$ s and additionally decreases the collector current slew rate during turn-off.



**Figure 7** Switching behavior of an FZ1600R17HP4\_B2 IHMB module utilizing the 2ED300E17-SFO combined with the MA400E17 with short circuit protection disabled in Figure 7a and enabled Figure 7b

## 3.5 Active clamping – boosted version

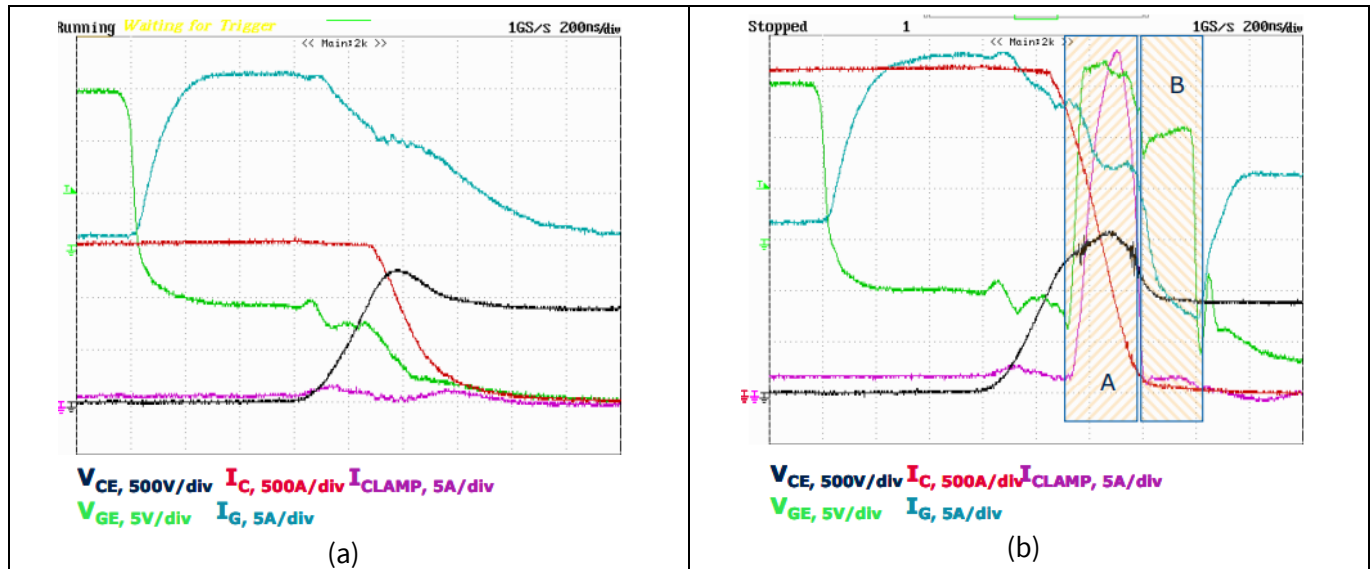
Active clamping is a technique which keeps transient overvoltages below the critical limits when the IGBT switches off. The standard approach to active clamping is to use a chain of avalanche diodes connected between the auxiliary collector and the gate of an IGBT module. When the Collector-Emitter voltage 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 turn off process is prolonged. 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 within the MA40xExx is based on an improved variant of the active clamping as described above. The clamping diodes are connected directly to the IGBT's gate but also to the input of the amplifier located on the MA40xExx. Therefore the major amount of current for recharging the gate is derived from the gate driver power supply instead of being drained through the clamping diodes. This provides more consistent clamping voltage due to operating the clamping diodes at a lower current level and furthermore enables the clamping circuit to be designed independently from the selected external gate resistor.

Figure 8 below displays the switching behavior of a FZ1600R17HP4 IGBT module at 900V DC voltage. During the turn off sequence, the gate current  $I_G$  from the booster, the current  $I_{CLAMP}$  through the active clamping diodes, the gate voltage  $V_{GE}$ , the IGBT collector emitter voltage  $V_{CE}$  and the IGBT current  $I_C$  have been monitored. At the nominal current in figure 8a, the magnitude of the IGBT collector emitter voltage does not exceed the breakdown voltage of the avalanche diodes. The current through the diodes remains close to zero. At increased

## Electrical features

current levels, switching leads to an overshoot exceeding the avalanche diode breakdown voltage. The diodes now conduct high peak currents as marked in region A. This current leads to recharging of the gate by activating the booster stage and turning on the gate-voltage again. The IGBT is hold in linear operation with decreasing collector current. As a consequence, the voltage across the device is reduced. As soon as the overvoltage gets down to the desired level, the clamping diodes return to blocking state turning off the gate as marked in region B. The turn-off procedure of the IGBT continues as desired.



**Figure 8** Switching behavior of the FZ1600R17HP4\_B2 IHM module with boosted active clamping where: a)  $V_{DC}=900V$ ,  $I_C=1600A$ , b)  $V_{DC}=900V$ ,  $I_C=3200A$ ,  $R_{Goff}=0,47\Omega$  and  $T_j=25^\circ C$

## 3.6 Maximum switching frequency

The switching frequency of an IGBT is limited either by the maximum power of the driver 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 level 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 operating temperature allowed for the PCB in use, i.e.  $105^\circ C$  for a standard FR4 material.

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

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

### Equation 1

The parameters used describe:

$P_{dis}$  the power dissipated [W],

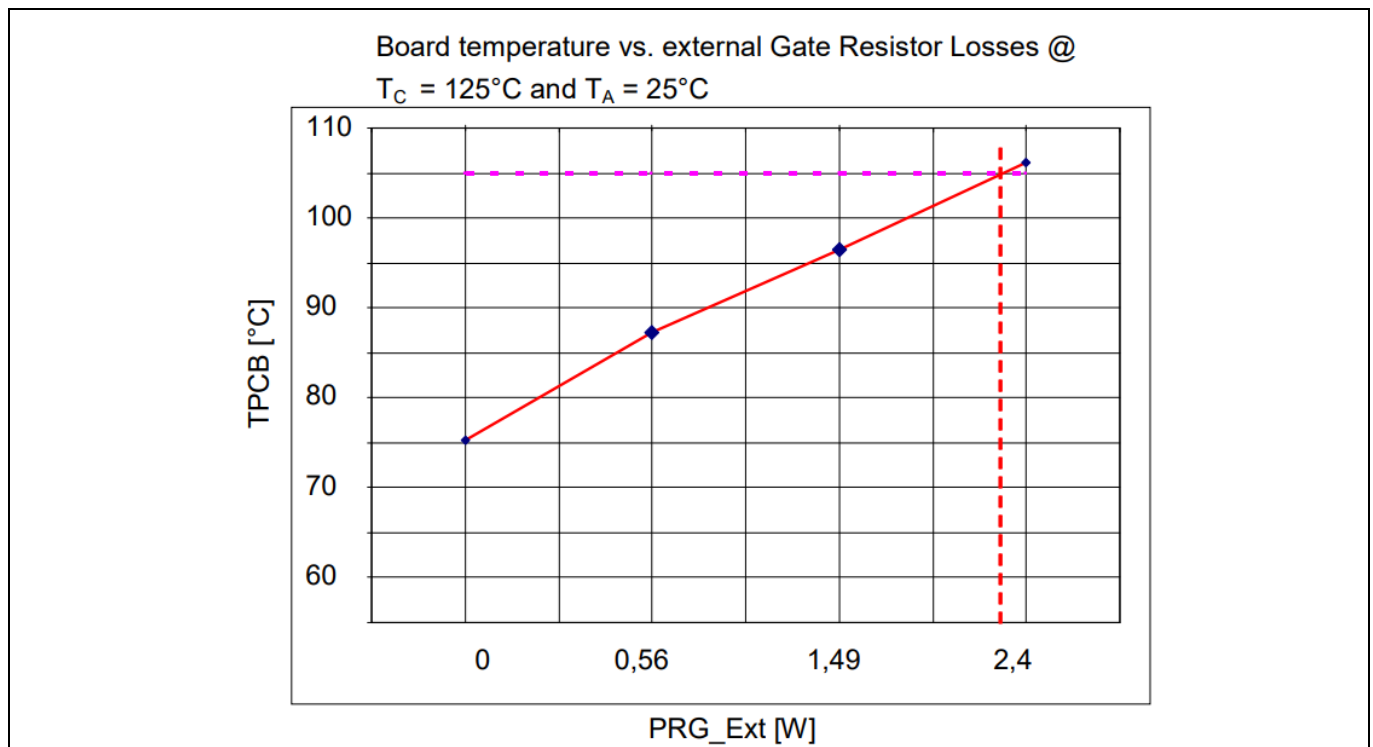
$\Delta V_{out}$  the voltage step at the driver output [V]

$f_s$  the switching frequency [Hz],

$Q_G$  the IGBT gate charge for the given gate voltage range as given in the datasheet

## Electrical features

The complete gate resistor consists of the internal gate resistor  $R_{GINT}$  and an external gate resistor  $R_{GEXT}$  mounted on the MA40xE12/E17. Due to that, a part of the according losses will be dissipated directly through the DCB into the base plate, whereas the other part of the power losses will be dissipated externally to the ambient air and into the PCB. The ratio of the losses dissipated internally  $P(R_{GINT})$  and externally  $P(R_{GEXT})$  corresponds directly to the ratio of the mentioned resistors  $R_{GINT}$  and  $R_{GEXT}$ . Figure 9 presents a measurement result showing the external gate resistor temperature as function of the losses generated in that resistor. It can be read from the graph, that for the ambient temperature of 25°C and the base plate temperature of 125°C the maximum temperature of the PCB reaches 105°C with power losses in  $R_{GEXT}$  equal to 1.1W. In that case the limiting factor for the switching frequency is not the DC/DC converter with its available power of 4W per channel. Operation is limited due to the maximum temperature of the PCB. Higher switching frequency can only be obtained by utilizing a PCB with higher melting temperature or resistors with improved thermal transfer to ambient.



**Figure 9** MA400E12/17 PCB temperature vs. gate resistor power losses

In order to calculate the allowed power losses  $P(R_{EXT})$  when the base plate and the ambient temperatures differ from the example shown above, formula (2) can be used.

$$P(R_{EXT}) = \frac{(105^{\circ}\text{C} - T_C / ^{\circ}\text{C})}{71} + \frac{(105^{\circ}\text{C} - T_A / ^{\circ}\text{C})}{71}$$

### Equation 2

Finally, the suggested IGBT maximum switching frequency for a given  $T_C$  and a  $T_A$  for the MA400Exx used in combination with the 2ED300E17-SFO is given by formula (3).

## Electrical features

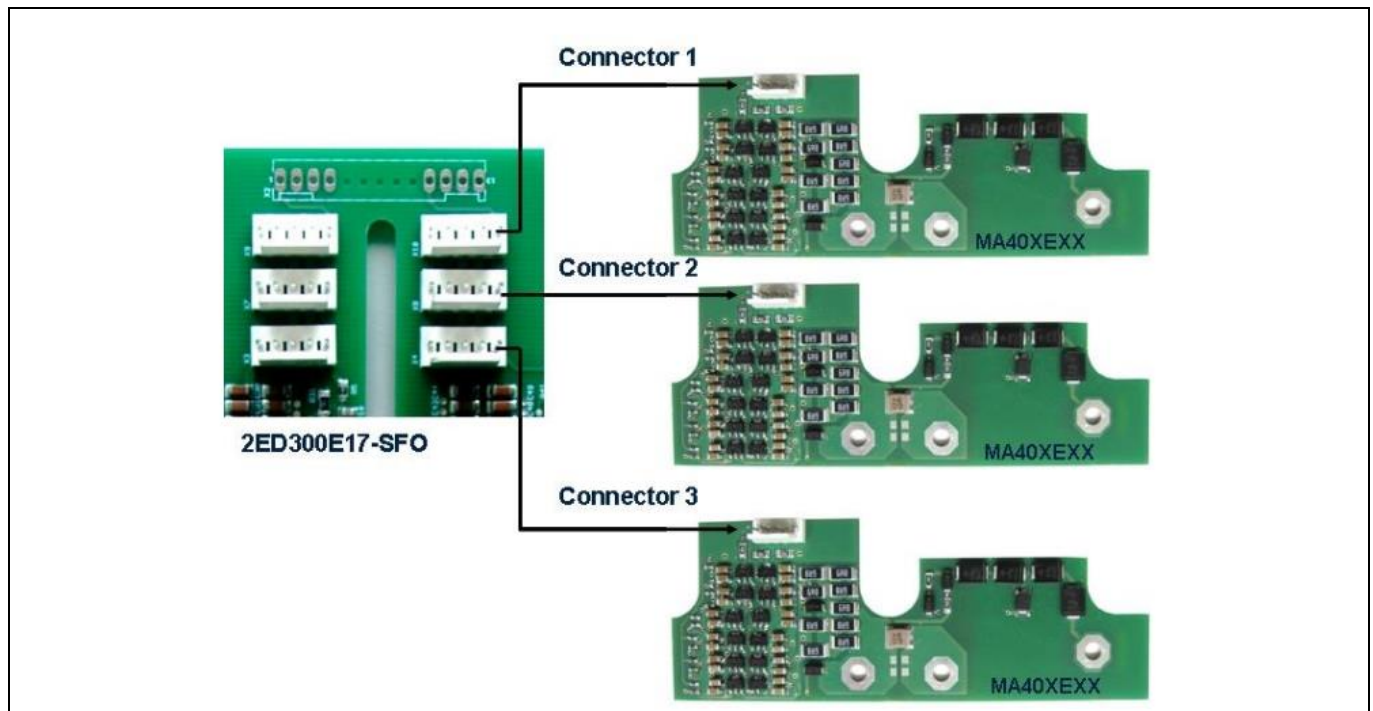
$$\frac{f_s}{\text{Hz}} = \frac{\frac{P(R_{EXT})}{W} \cdot \left( \frac{R_{INT}}{\Omega} + \frac{R_{EXT}}{\Omega} \right)}{30 \cdot k \cdot \frac{R_{EXT}}{\Omega} \cdot \frac{Q_g}{\mu C}}$$

**Equation 3**

The factor  $k=1.2$  represents a set of tolerances and is based on measurements and experiences.

### 3.7 Parallel operation

The Flexible Starter Kit consisting of one 2ED300E17-SFO, one 2ED300E17-S /-ST driver board and the MA40xExx module adapter boards can be used for driving one IHM module or up to three paralleled IHM modules as sketched in Figure 10. In this case all the IHM modules have dedicated MA40xExx boards connected to the 2ED300E17-SFO adapter board. It must be noted that RSSD in every case should be selected according to [AN2007-05](#) chapter 3.5.



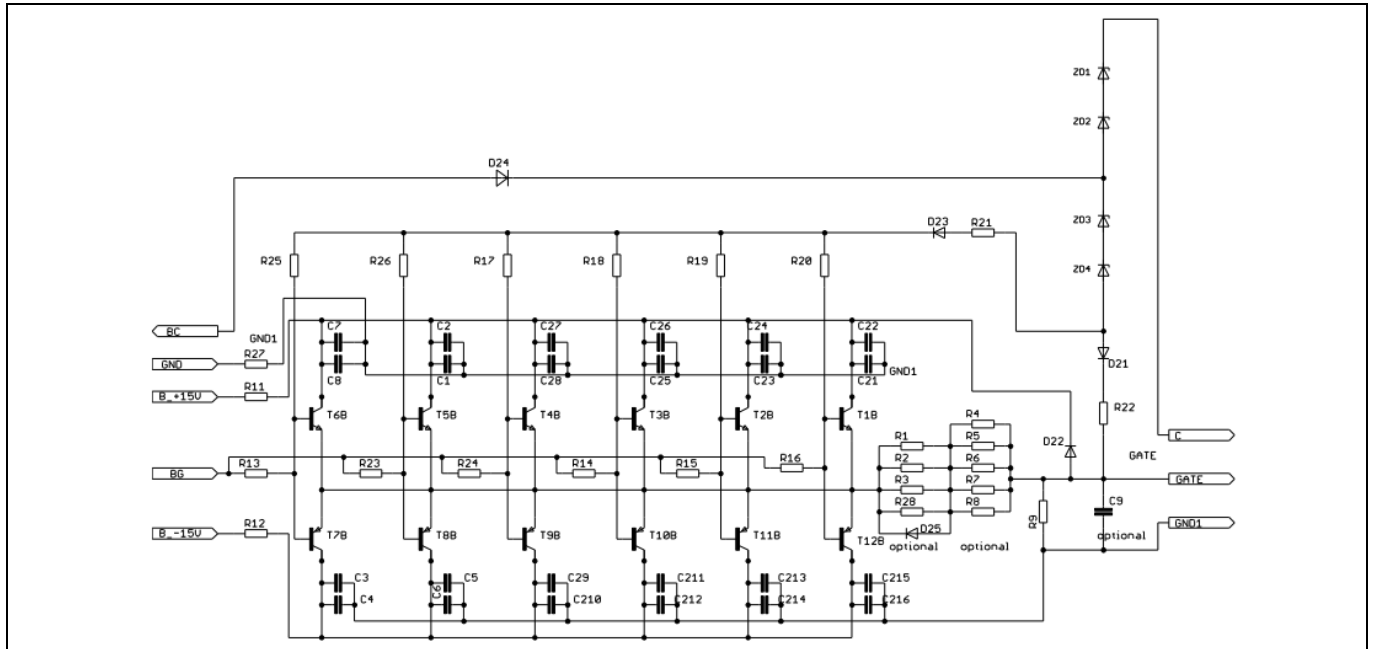
**Figure 10** Connections between three MA40xExx and one 2ED300E17-SFO operating three IHM-Modules in parallel connection

## Schematic and Layout

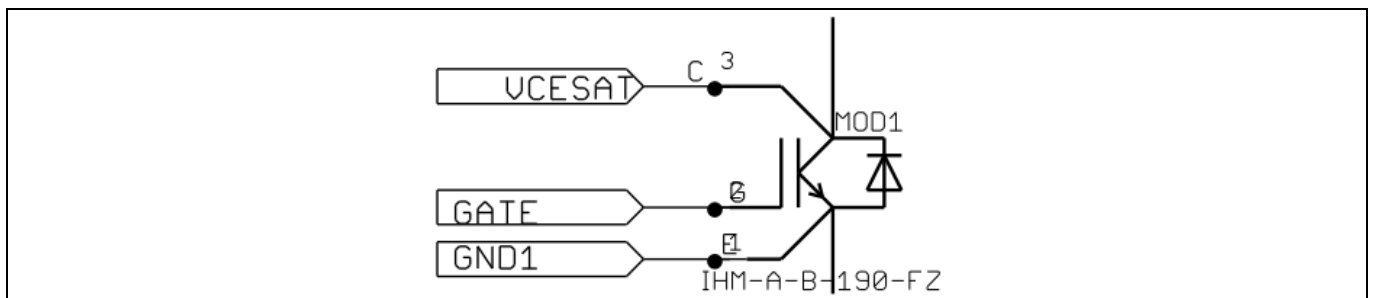
# 4 Schematic and Layout

To meet the individual customer requirements and to make the evaluation board a basis for further development or modification, all necessary technical data including schematics, PCB layout and components are included in this chapter.

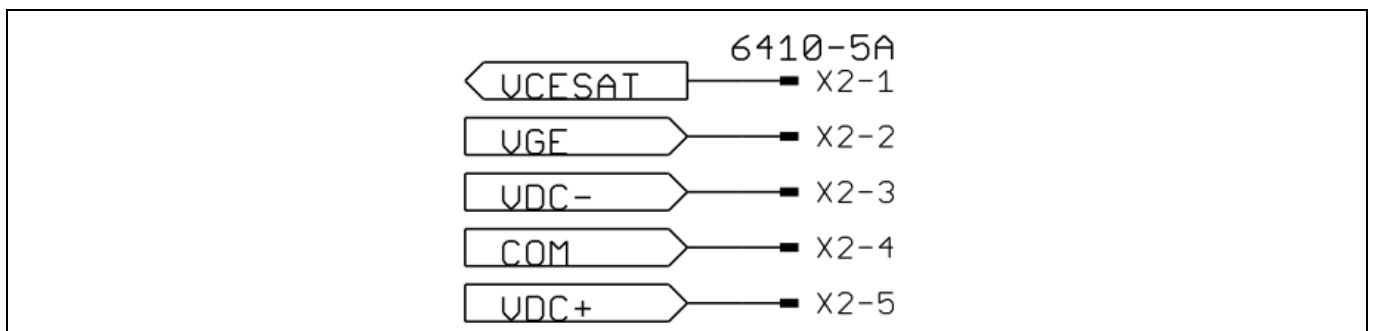
## 4.1 Schematic



**Figure 11 The MA40xExx – booster stage**



**Figure 12 The MA40xExx – IGBT connections**



**Figure 13 The MA40xExx – connectors**

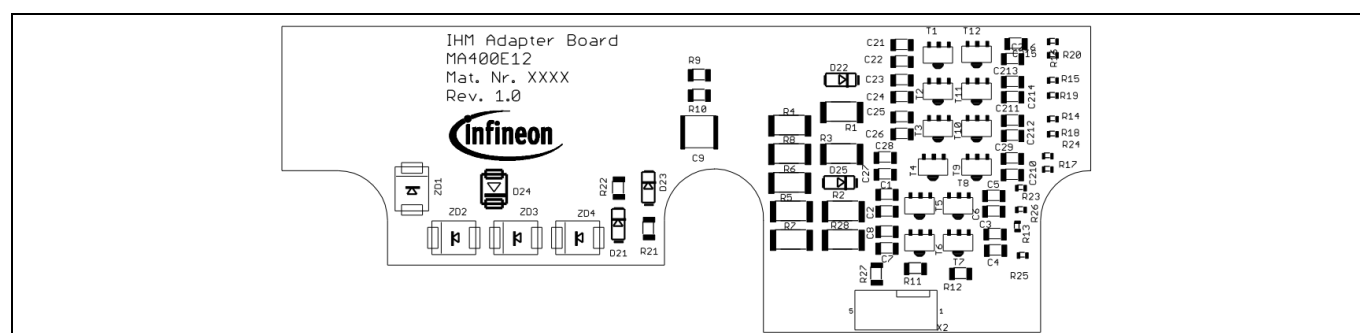
## Schematic and Layout

### 4.2 Assembly drawing

Basic circuit and layout for the MA400E12 or E17 and MA401E12 or E17 are similar. To adapt the board to the proper voltage rating the active clamping diodes have to be chosen according to Table 3. Figure 14 gives an overview of the assembly of the MA400E12 Adapter board.

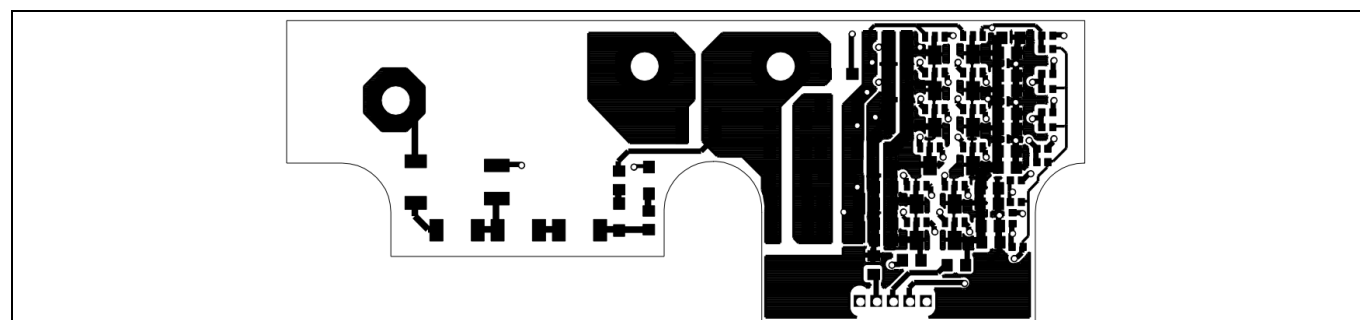
**Table 3 The external electrical signals description of MA400Exx and MA401Exx**

Board Names	Assembled diodes	Types of assembled diodes
MA40xE12_EVAL	ZD1, ZD2, ZD3, ZD4	SMJC188A
MAx0xE17_EVAL	ZD1, ZD2, ZD3	1.5SMC440A
	ZD4	Shorted by wire or 0R resistor

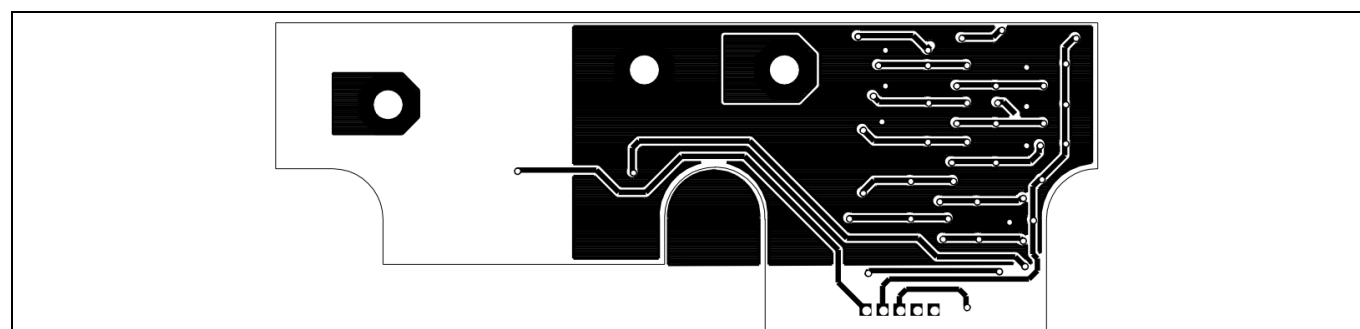


**Figure 14 The MA400E12 – assembly drawing**

### 4.3 Layout



**Figure 15 The MA400E12 – Top layer**



**Figure 16 The MA400E12 – Bottom layer**



## Schematic and Layout

### 4.4 Bill of Material – MA400E12\_EVAL / MA401E12\_EVAL

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 C0G less or equal to  $\pm 5\%$  and for capacitors of the type X7R less or equal to  $\pm 10\%$ .

**Table 4 The external electrical signals description of MA400Exx and MA401Exx**

Pin	Value / Type	Package size imperial	QTY	Name Part	Recommended Manufacturer	Assembly
Resistor	see chapter 3.2*	2512	9	R1, R2, R3, R4, R5, R6, R7, R8, R28	special pulse resistors	no
Resistor	10k	1206	1	R9	no special	yes
Resistor	1R	1206	4	R11, R12, R22, R27	special pulse	yes
Resistor	10R	1206	1	R21	no special	yes
Resistor	10R	0603	6	R17, R18, R19, R20, R25, R26	no special	yes
Resistor	27R	0603	6	R13, R14, R15, R16, R23, R24	no special	yes
Capacitor	variable	0805	2	C17, C217	no special	no
Capacitor	variable	C2220	1	C9	optional	no
Capacitor	4 $\mu$ 7/25V/X7R	1206	24	C1, C2, C3, C4, C5, C6, C7, C8, C21, C22, C23, C24, C25, C26, C27, C28, C29, C210, C211, C212, C213, C214, C215, C216	Murata	yes
Semiconductor	ZXTN2010Z	SOT89	6	T1, T2, T3, T4, T5, T6	Diodes	yes
Semiconductor	ZXTP2012Z	SOT89	6	T7, T8, T9, T10, T11, T12	Diodes	yes
Semiconductor	ES1B (see chapter 3.2)	DO214AC	4	D5, D6, D25, D26	Vishay	no
Semiconductor	ES1B	DO214AC	4	D21, D22, D23, D25	Vishay	yes
Semiconductor	STTH112U	SMB	1	D24	STM	yes
Semiconductor	1.5SMC440A	SMC	3	ZD1, ZD2, ZD3, ZD4	Vishay	yes
Connector	6410-5A		1	X2	Molex (22-27-2051)	yes

\*Pulse power rated types

### 4.5 Bill of Material – MA400E17 EVAL / MA401E17 EVAL

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 C0G less or equal to  $\pm 5\%$  and for capacitors of the type X7R less or equal to  $\pm 10\%$ .

**Schematic and Layout**
**Table 5 Bill of Material for the MA400E17 adapter board**

Pin	Value / Type	Package size imperial	QTY	Name Part	Recommended Manufacturer	Assembly
Resistor	see chapter 3.2*	2512	9	R1, R2, R3, R4, R5, R6, R7, R8, R28	special pulse resistors	no
Resistor	10k	1206	1	R9	no special	yes
Resistor	1R	1206	4	R11, R12, R22, R27	special pulse	yes
Resistor	10R	1206	1	R21	no special	yes
Resistor	10R	0603	6	R17, R18, R19, R20, R25, R26	no special	yes
Resistor	27R	0603	6	R13, R14, R15, R16, R23, R24	no special	yes
Capacitor	variable	0805	2	C17, C217	no special	no
Capacitor	variable	C2220	1	C9	optional	no
Capacitor	4μ7/25V/X7R	1206	24	C1, C2, C3, C4, C5, C6, C7, C8, C21, C22, C23, C24, C25, C26, C27, C28, C29, C210, C211, C212, C213, C214, C215, C216	Murata	yes
Semiconductor	ZXTN2010Z	SOT89	6	T1, T2, T3, T4, T5, T6	Diodes	yes
Semiconductor	ZXTP2012Z	SOT89	6	T7, T8, T9, T10, T11, T12	Diodes	yes
Semiconductor	ES1B (see chapter 3.2)	DO214AC	4	D5, D6, D25, D26	Vishay	no
Semiconductor	ES1B	DO214AC	4	D21, D22, D23, D25	Vishay	yes
Semiconductor	STTH112U	SMB	1	D24	STM	yes
Semiconductor	1.5SMC440A	SMC	3	ZD1, ZD2, ZD3	Vishay	yes
Semiconductor		SMC	1	ZD4 (Shorted by 0R)	Vishay	no
Connector	6410-5A		1	X2	Molex (22-27-2051)	yes

\*Pulse power rated types

**How to order Evaluation Driver Boards**

## **5 How to order 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 Infineon Web Page: [www.infineon.com](http://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](mailto:WAR-IGBT-Application@infineon.com)

IFX order number for MA400E12: SP000879862

IFX order number for MA400E17: SP000879872

IFX order number for MA401E12: SP000880276

IFX order number for MA401E17: SP000880282

IFX order number for 2ED300E17-SFO: SP000355559

IFX order number for 2ED300C17-S: SP000359184

IFX order number for 2ED300C17-ST: SP000359188

## References

## References

[1]

**Revision history****Revision history**

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Revision 1.10	2014-02-01	
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**Do you have a question about this document?**

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

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