

## Evaluation Driver Boards for EconoDUAL™ 3 and EconoPACK™ + modules

IFAG IMM INP M AE

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

Edition 2011-02-02

Published by

Infineon Technologies AG

59568 Warstein, Germany

© Infineon Technologies AG 2011.

All Rights Reserved.

Attention please!

THE INFORMATION GIVEN IN THIS APPLICATION NOTE IS GIVEN AS A HINT FOR THE IMPLEMENTATION OF THE INFINEON TECHNOLOGIES COMPONENT ONLY AND SHALL NOT BE REGARDED AS ANY DESCRIPTION OR WARRANTY OF A CERTAIN FUNCTIONALITY, CONDITION OR QUALITY OF THE INFINEON TECHNOLOGIES COMPONENT. THE RECIPIENT OF THIS APPLICATION NOTE MUST VERIFY ANY FUNCTION DESCRIBED HEREIN IN THE REAL APPLICATION. INFINEON TECHNOLOGIES HEREBY DISCLAIMS ANY AND ALL WARRANTIES AND LIABILITIES OF ANY KIND (INCLUDING WITHOUT LIMITATION WARRANTIES OF NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS OF ANY THIRD PARTY) WITH RESPECT TO ANY AND ALL INFORMATION GIVEN IN THIS APPLICATION NOTE.

Information

For further information on technology, delivery terms and conditions and prices please contact your nearest Infineon Technologies Office ([www.infineon.com](http://www.infineon.com)).

Warnings

Due to technical requirements components may contain dangerous substances. For information on the types in question please contact your nearest Infineon Technologies Office. Infineon Technologies Components may only be used in life-support devices or systems with the express written approval of Infineon Technologies, if a failure of such components can reasonably be expected to cause the failure of that life-support device or system, or to affect the safety or effectiveness of that device or system. Life support devices or systems are intended to be implanted in the human body, or to support and/or maintain and sustain and/or protect human life. If they fail, it is reasonable to assume that the health of the user or other persons may be endangered.

AN 2008-02

Revision History: date (11-02-02) , V1.3

Previous Version: V1.2

Page: Subjects Improvement of the active gate clamping circuit

Authors: Alain Siani IFAG IMM INP M AE, Uwe Jansen IFAG IMM INP M AE

We Listen to Your Comments

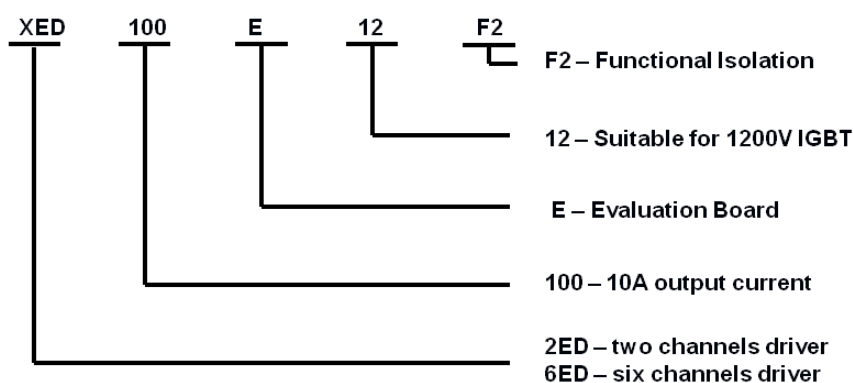
Any information within this document that you feel is wrong, unclear or missing at all? Your feedback will help us to continuously improve the quality of this document. Please send your proposal (including a reference to this document) to: [\[WAR-IGBT-Application@infineon.com\]](mailto:WAR-IGBT-Application@infineon.com)

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### Table of contents

|     |   |    |
|-----|---|----|
| 1.1 | 1   |    |
| 1   | Introduction .....  | 4  |
| 2   | Design features.....  | 5  |
| 2.1 | Main features.....  | 5  |
| 2.2 | Key data .....  | 6  |
| 2.3 | Pin assignment.....   | 7  |
| 2.4 | Mechanical dimensions of the EconoDUAL™ 3 Driver Board .....      | 8  |
| 2.5 | Mechanical dimensions of the EconoPACK™ + Driver Board.....       | 8  |
| 3   | Electrical Features .....   | 9  |
| 3.1 | Power Supply .....  | 9  |
| 3.2 | Input logic – PWM signals.....                                    | 9  |
| 3.3 | Maximum switching frequency .....                                 | 9  |
| 3.4 | Booster .....   | 11 |
| 3.5 | Short circuit protection and active clamping .....                | 11 |
| 3.6 | Fault output .....  | 12 |
| 3.7 | Temperature measurement.....                                      | 13 |
| 4   | Switching losses .....  | 15 |
| 4.1 | Turn-on losses.....   | 15 |
| 4.2 | Turn-off losses.....  | 17 |
| 5   | Schematic, Layout and Bill of Material - EconoDUAL™ 3 board ..... | 18 |
| 5.1 | Schematic.....  | 18 |
| 5.2 | Assembly drawing .....  | 20 |
| 5.3 | Layout.....   | 21 |
| 5.4 | Bill of Material.....   | 22 |
| 5.5 | Gate resistor list .....  | 24 |
| 6   | Schematic, Layout and Bill of Material - EconoPACK™ + board ..... | 25 |
| 6.1 | Schematic.....  | 25 |
| 6.2 | Assembly drawing .....  | 27 |
| 6.3 | Layout.....   | 28 |
| 6.4 | Bill of material.....   | 30 |
| 6.5 | Gate resistor list .....  | 33 |
| 7   | How to order Evaluation Driver Boards.....                        | 33 |
| 8   | References .....  | 33 |

#### Part number explanation:



# Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

## 1 Introduction

The Evaluation Driver Board 2ED100E12-F2 for EconoDUAL™ 3 modules as can be seen in Figure 1 and the Evaluation Driver Board 6ED100E12-F2 for EconoPACK™ + modules, shown in Figure 2, were developed to support customers during their first steps designing applications with these modules. The basic version of each board is available from Infineon in small quantities. The properties of these parts are described in the following chapters 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 his specific requirements.

The design of the 2ED100E12-F2 and the 6ED100E12-F2 was performed with respect to the environmental conditions described as design target in this document. The requirements for lead-free reflow soldering have been considered when components were selected. The design was tested as described in this documentation but not qualified regarding manufacturing and operation in the whole operating ambient temperature range or lifetime.

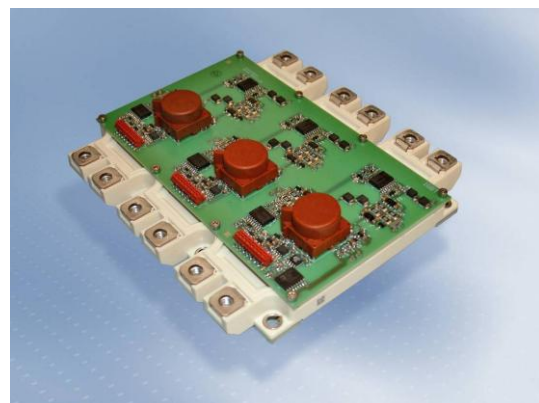
The boards provided by Infineon are subjected to functional testing only.

Due to their purpose Evaluation Boards are not subjected to the same procedures regarding Returned Material Analysis (RMA), Process Change Notification (PCN) and Product Discontinuation (PD) as regular products.

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



**Figure 1** The 2ED100E12-F2 Evaluation Driver Board mounted on the top of the EconoDUAL™ 3 module



**Figure 2** The 6ED100E12-F2 Evaluation Driver Board mounted on the top of the EconoPACK™ + module

# Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

## 2 Design features

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

### 2.1 Main features

The 2ED100E12-F2 and the 6ED100E12-F2 Evaluation Driver Board offer the following features:

- Dual channel IGBT driver in 2ED100E12-F2 version, adapted for use with IGBT4
- Six channel IGBT driver in 6ED100E12-F2 version
- Electrically and mechanically suitable for 600 V and 1200 V EconoDUAL™ 3 or EconoPACK™ + IGBT modules
- Includes DC/DC power supply with short circuit protection
- Isolated temperature measurement
- Short circuit protection with  $t_{off} < 6 \mu s$
- Under Voltage Lockout of IGBT driver IC
- Positive logic with 5 V CMOS level for PWM and fault signals
- One fault output signal for each leg
- PCB is designed to fulfill the requirements of IEC61800-5-1, pollution degree 2, overvoltage category II

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 2.2 Key data

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

**Table 1 Key data and characteristic values (typical values)**

| Parameter     |  | Value       | Unit       |
|---------------|--|-------------|------------|
| $V_{DC}$      | primary DC/DC voltage supply   | +15 ±0.5    | V          |
| $V_{CC}$      | primary supply voltage for logic devices                                   | +5 ±0.5     | V          |
| $V_{LogicIN}$ | PWM signals for high side and low side IGBT                                | 0 / +5      | V          |
| $V_{FAULT}$   | /FAULT detection output  | 0 / +5      | V          |
| $I_{FAULT}$   | max. /FAULT detection output load current                                  | 10          | mA         |
| $V_{RST}$     | /RST input   | 0 / +5      | V          |
| $I_{DC}$      | primary DC/DC current drawn per leg  | 40          | mA         |
| $I_{CC}$      | primary current drawn for logic devices per leg                            | 25          | mA         |
| $V_{out}$     | drive voltage level for high side and Low side channel                     | +16 / -8    | V          |
| $I_G$         | max. peak output current   | ±10         | A          |
| $P_{DC/DC}$   | max. DC/DC output power high and low side                                  | 3           | W          |
| $f_s$         | max. PWM signal frequency for high and low side <sup>1)</sup>              | 100         | kHz        |
| $t_{PDELAY}$  | propagation delay time   | 200         | ns         |
| $t_{PDISTO}$  | input to output propagation distortion                                     | 15          | ns         |
| $V_{Desat}$   | Desaturation reference level   | 9           | V          |
| $d_{max}$     | max. duty cycle  | 100         | %          |
| $V_{CES}$     | max. collector – emitter voltage on IGBT                                   | 600/1200    | V          |
| $V_{TEMP}$    | temperature measurement output voltage                                     | digital 0/5 | V          |
| $I_{TEMP}$    | max. temperature measurement load current                                  | 5           | mA         |
| $T_{op}$      | operating temperature design target <sup>2)</sup>                          | -40...+85   | °C         |
| $T_{sto}$     | storage temperature design target  | -40...+85   | °C         |
| $U_{is,eff}$  | Isolation voltage <sup>3)</sup> Transformer Vacuumschmelze                 | 500         | $V_{AC}$   |
| $V_{IORM}$    | Maximum Repetitive Insulation Voltage <sup>4)</sup> 1ED020112-F Driver IC  | 1420        | $V_{peak}$ |
| $V_{IORM}$    | Max. working insulation voltage <sup>5)</sup> AD7400 Sigma-Delta Converter | 891         | $V_{peak}$ |

1) The maximum switching frequency for every EconoDUAL™ 3 or EconoPACK™ + module type should be calculated separately. Limitation factors are: max. DC/DC output power of 1.5 W per channel and max. PCB board temperature measured around gate resistors of 105 °C for used FR4 material. For detailed information see chapter 2.3

2) Maximum operating temperature strictly depends on load and cooling conditions. For detailed description see chapter 2.3

3) Values defined in datasheets: T60403-D4615-X054 date: 21.03.2000

4) 1ED020112-F Datasheet, Version 2.2, December 2009

5) AD7400 1/11 – Revision C

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

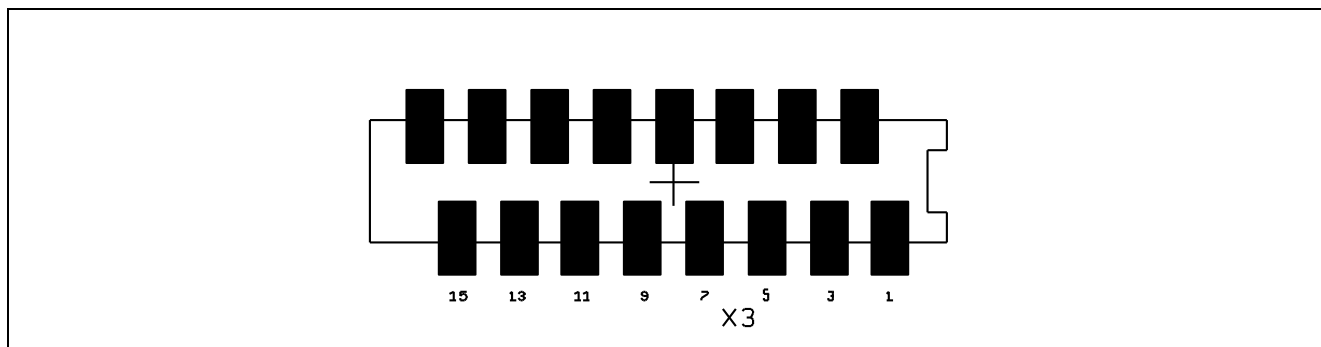
### 2.3 Pin assignment

Except pin 14 of the connectors X1 and X2 of EconoPACK™ + driver board, all connectors for both EconoDUAL™ 3 and EconoPACK™ + board are configured as listed in Table 2.

Table 2 depicts the pin assignment of connector X3 shown in Figure 3.

**Table 2 Inputs and outputs of 6ED100E12-F2 for connector X3**

| Pin   | Label        | Function  |
|-------|--------------|---|
| X3.1  | MClock       | Clock out for temperature measurement             |
| X3.2  | Supply       | +15 V Primary voltage for DC/DC converter         |
| X3.3  | GND          | Primary ground for DC/DC converter supply voltage |
| X3.4  | Supply       | +15 V Primary voltage for DC/DC converter         |
| X3.5  | TOP IN-      | PWM signal for high side IGBT, negative logic     |
| X3.6  | TOP IN+      | PWM signal for high side IGBT, positive logic     |
| X3.7  | TOP RDY      | Ready signal for high side IGBT                   |
| X3.8  | TOP /FLT     | Fault detection output high side IGBT             |
| X3.9  | TOP/BOT /RST | Reset signal for high and low side IGBT -Driver   |
| X3.10 | BOT /FLT     | Fault detection output low side IGBT              |
| X3.11 | BOT RDY      | Ready signal for low side IGBT                    |
| X3.12 | BOT IN-      | PWM signal for low side IGBT, negative logic      |
| X3.13 | BOT IN+      | PWM signal for low side IGBT, positive logic      |
| X3.14 | TEMP-Digital | Sigma / Delta signal for temperature measurement  |
| X3.15 | +5V          | +5 V Voltage supply for logic devices             |
| X3.16 | Signal GND   | Primary ground logic devices                      |



**Figure 3 The 6ED100E12-F2 Evaluation Driver Board connector layout of X3**

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 2.4 Mechanical dimensions of the EconoDUAL™ 3 Driver Board

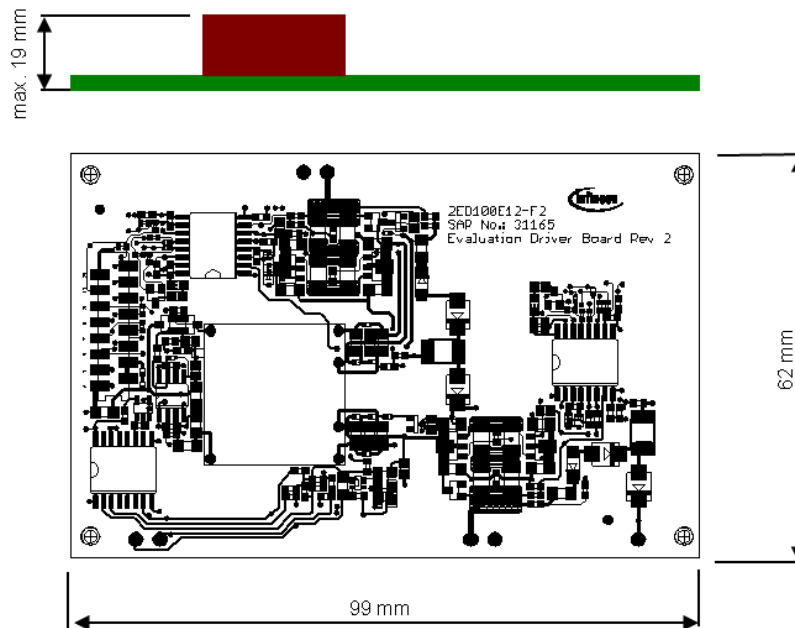


Figure 4 Dimensions of the 2ED100E12-F2 Driver Board

### 2.5 Mechanical dimensions of the EconoPACK™ + Driver Board

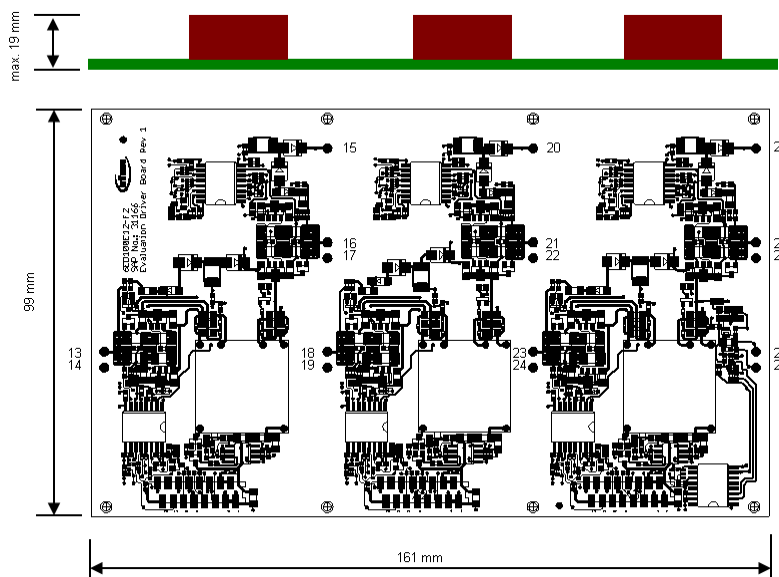


Figure 5 Dimensions of the 6ED100E12-F2 Driver Board

Both Driver Boards should be fastened by self tapping screws and soldered to the auxiliary connectors on top of the IGBT module.

Clearance and creepage distances for EconoDUAL™ 3 and EconoPACK™ + Driver Boards:  
Primary/Secondary is not less than 8 mm and Secondary/Secondary is not less than 4 mm.



## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 3 Electrical Features

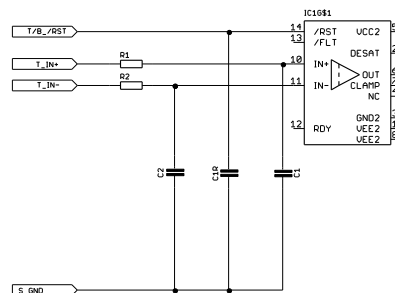
The following chapter describes the board's operation in the evaluation setup. Please note that the following paragraphs describe the circuits of the 2ED100E12-F2 which has been modified compared to the last revision of this AN to drive IGBT4 modules and to reduce the susceptibility to erroneous triggering of the  $V_{cesat}$ -detection. The same changes also are applied to the 6ED100E12-12-F2, but layout and part list of this board as provided in chapter 7 still represent the initial design.

#### 3.1 Power Supply

The 2ED100E12-F2 and the 6ED100E12-F2 have an integrated DC/DC converter for each leg, which generates the required secondary isolated unsymmetrical supply voltage of +16 V / -8 V. High and Low side driver voltages are independently generated by using one unipolar input voltage of 15 V. Additionally, the power supply is protected against gate – emitter short circuit of the IGBTs. In case of DC/DC converter overload, the output voltage drops. The Under Voltage Lock Out function ensures gate driver operation only to take place within specified IC supply voltages range. The fault is reported to the driver's primary side.

#### 3.2 Input logic – PWM signals

The Evaluation Driver Boards are dedicated to solderable IGBT modules. It is necessary to connect two separate PWM signals for EconoDUAL™ 3 IGBT modules and six separate PWM signals in case of EconoPACK™ + IGBT modules. An individual signal for each IGBT channel is necessary. Parts of the schematic for a single driver are depicted in Figure 6. The signals dedicated to High- and Low-Side need to have the correct dead time. Both Evaluation Driver Boards do not provide dead time generation. For suggested gate resistor values according to Table 5 on page 24, the recommended minimum dead time  $t_{TD}$  is 1 $\mu$ s. If larger gate resistors are used please refer to [1].



**Figure 6 Schematic detail of the input circuit for a single driver.**

The schematic in Figure 6 shows parts of the driver circuit with positive logic. IN+ is used as signal input whereas IN- is used as enable signal. Therefore a +5 V signal on the IN+ input pin and a GND signal on the IN- input pin is necessary to turning-on the IGBT. To operate the whole circuit with negative logic the capacitors C1 and C2 on the input pins have to be swapped. Otherwise this would cause an additional delay. IN+ will then operate as an enable signal.

#### 3.3 Maximum switching frequency

The switching frequency of an IGBT is limited either by the maximum output power of the driver voltage 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 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 external gate resistors
- $P(R_{INT})$  = dissipated power internal gate resistor
- $\Delta V_{out}$  = voltage step at the driver output
- $f_s$  = switching frequency
- $Q_G$  = IGBT gate charge for the given gate voltage range

The complete gate resistor consists of the internal gate resistor together with an external gate resistor and due to that, a part of the IGBT drive power losses will be dissipated directly in the PCB, whereas the other part of the losses will be dissipated externally to the ambient air. 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. Corresponding to -8/+16V operation the datasheet value of  $Q_{ge}$  needs to be reduced by 20%.

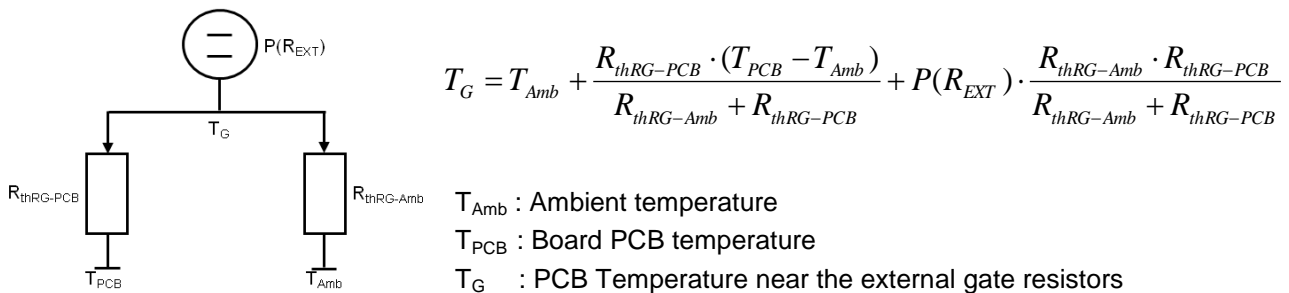
Due to the PCB temperature criteria the power dissipated in external gate resistors  $P(R_{EXT})$  has to be considered for the thermal design.

Based on experimentally determined board temperatures the following thermal resistances of the Evaluation Boards have been calculated as shown in Figure 7.

Thermal resistance, gate resistors to PCB:  $R_{thRG-PCB} = 45 \text{ K/W}$

Thermal resistance, gate resistors to ambient:  $R_{thRG-Amb} = 39 \text{ K/W}$

Using these values, it is possible to determine the maximum board temperature, if the power losses of the external gate resistors, the maximum ambient temperature and the maximum PCB temperature are known:



**Figure 7 Thermal model of the Gate resistor.**

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 3.4 Booster

Figure 8 shows the output stage of the driver where two complementary pairs of transistors are used to amplify the driver IC's signal. This allows driving IGBTs that need more current than the driver IC can deliver. Two NPN transistors are used for turning-on the IGBT and two PNP transistors for turning-off the IGBT.

The transistors are dimensioned to provide enough peak current to drive all 600 V and 1200 V EconoDUAL™ 3 and EconoPACK™ + modules. The peak current can be calculated according to

Formula (2):

$$I_{peak} = \frac{\Delta V_{out}}{R_{INT} + R_{EXT} + R_{Driver}} \quad (2)$$

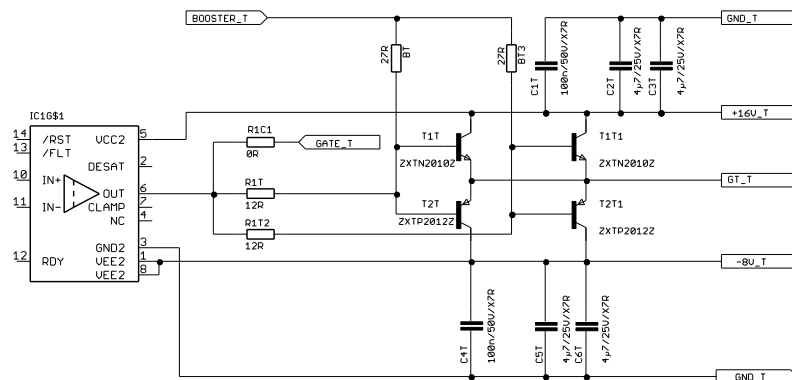


Figure 8 Driver output stage with booster

Gate resistors are connected in between booster stage and IGBT module gate connection. Suggested values are listed in table 5 on page 25 and table 7 on page 36. For some modules the value for these resistors is 0 Ω. In this case just a jumper is required. If resistors are needed, care should be taken that these resistors have a suitable rating for repetitive pulse power to avoid degradation.

### 3.5 Short circuit protection and active clamping

The short circuit protection of the Evaluation Driver Board basically relies on the detection of a voltage level higher than 9 V on the DESAT pin of the 1ED020112-F driver IC and the implemented active clamp function. Thanks to this operation mode, the collector-emitter overvoltage, which is a result of the stray inductance and the collector current slope, is limited.

The overvoltage shoots during turning-off changes as a function of the stray inductance, the current and the DC voltage. Figure 9 shows the parts of the circuit needed for the desaturation function and the active clamping. The EconoDUAL™ 3 driver board is equipped with an additional diode D1 to avoid a bypass current during the turning-on sequence.

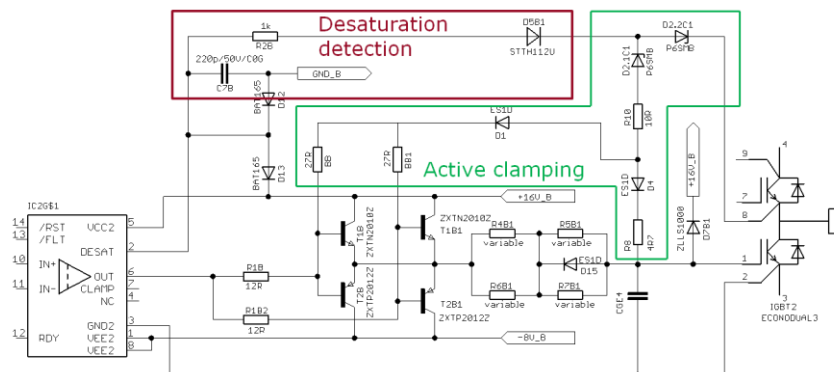


Figure 9 Desaturation detection and active clamping

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

Active clamping is a technique which keeps transient overvoltages below the critical limits when the IGBT turns-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 turning-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.

A typical turn-off waveform under short circuit condition of a FF600R12ME4 module at room temperature without any overvoltage limiting function is shown in Figure 10a. Under short circuit condition at room temperature with active clamp function a typical waveform is shown in Figure 10b.

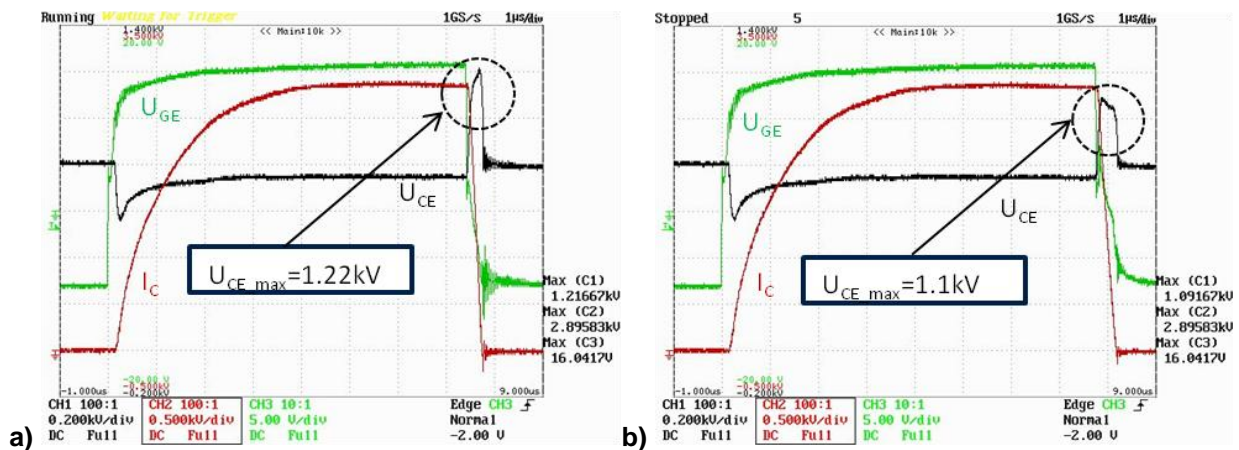


Figure 10 a) Short circuit without active clamping b) with active clamping function

### 3.6 Fault output

When a short circuit occurs, the voltage increase across the IGBT is detected by the desaturation protection of the 1ED02012-F and the IGBT is turning-off. The fault is reported to the primary side of the driver as a low active signal. A red LED is turning-on to signalize the failure condition. The /FLT status remains active as long as there is no reset signal applied to the driver. The /FLT signal is active low, the according schematic can be seen in Figure 11.

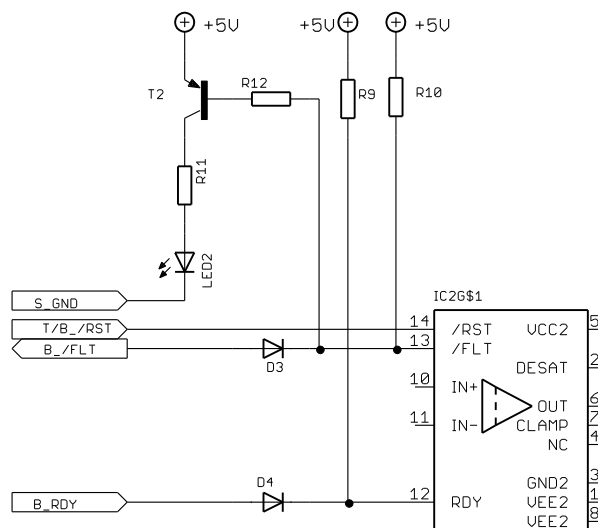


Figure 11 Fault output for a single driver

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 3.7 Temperature measurement

Based on the NTC built into both module types, the driver boards offer IGBT base plate temperature measurement in the range of -40 °C...150 °C. Both Evaluation Driver Boards work with a Sigma/Delta converter. Thus a digital signal is provided featuring the advantage that digital signal processing can be used without particular hardware efforts and that the subsequent error is low. However an analog signal can be produced with the use of the schematic in Figure 12.

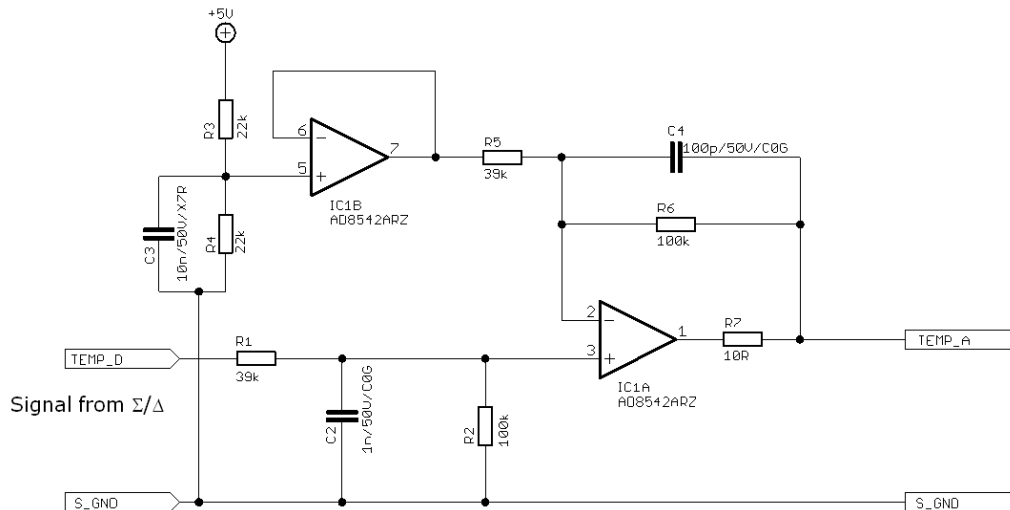


Figure 12 Schematic to convert digital  $\Sigma/\Delta$  to analog output

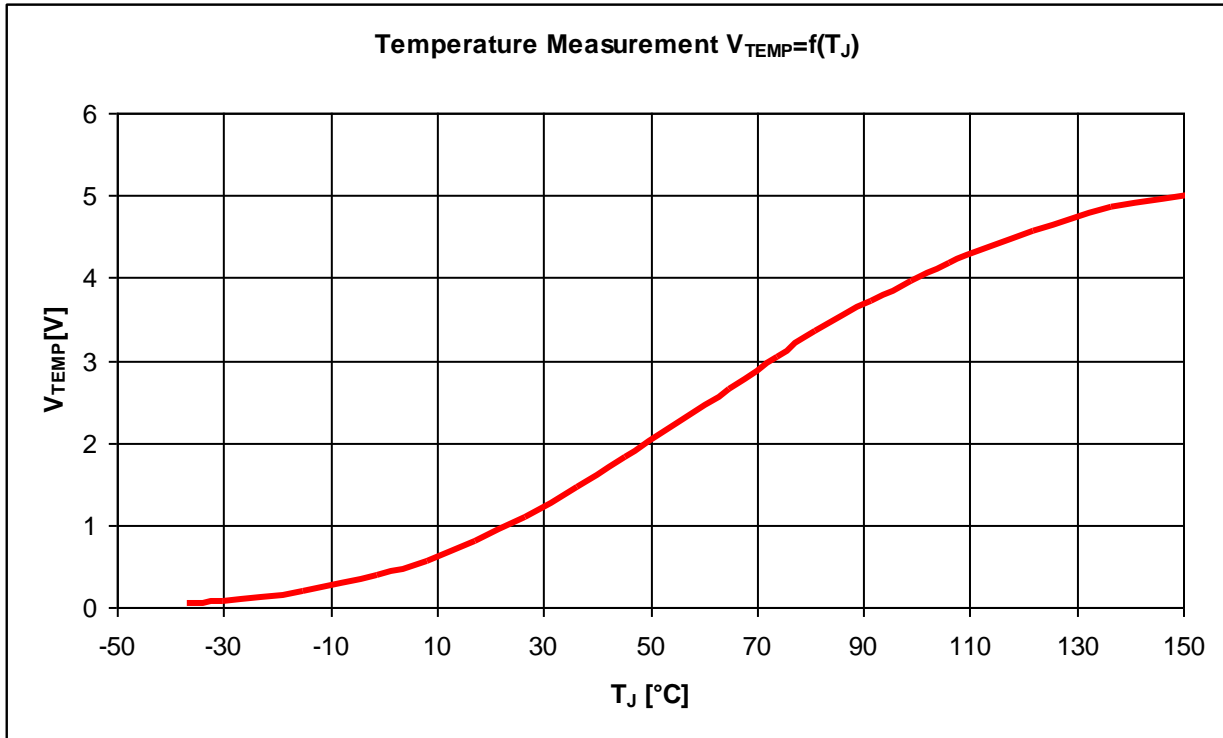
Table 3 Bill of Material  $\Sigma/\Delta$  to analog converter

| Type      | Qty | Value / Device | Package size imperial | Part Name | Recommended Manufacturer |
|-----------|-----|----------------|-----------------------|-----------|--------------------------|
| Capacitor | 1   | 100n/50V/X7R   | C0603                 | C1        |                          |
| Capacitor | 1   | 1n/50V/C0G     | C0603                 | C2        |                          |
| Capacitor | 1   | 10n/50V/X7R    | C0603                 | C3        |                          |
| Capacitor | 1   | 100p/50V/C0G   | C0603                 | C4        |                          |
| Amplifier | 1   | AD8542ARZ      | SOIC08                | IC1       | Analog Devices           |
| Resistor  | 2   | 39k            | R0603                 | R1, R5    |                          |
| Resistor  | 2   | 100k           | R0603                 | R2, R6    |                          |
| Resistor  | 2   | 22k            | R0603                 | R3, R4    |                          |
| Resistor  | 1   | 10R            | R0603                 | R7        |                          |

All electronic parts used in the design are lead-free with 260 °C soldering profile. 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  $\pm 10\%$ .

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

Using the base plate temperature and a thermal model, the junction temperature can be estimated. The complexity of the thermal model needed for this purpose depends on application and heat sink conditions as well as on requirements regarding accuracy and dynamic response. In case of a broken wire the output shuts down to 0 V. The relation between output voltage and base plate temperature is shown in Figure 13.



**Figure 13** Characteristics of the temperature measurement

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

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 4 Switching losses

The setup used for preparing this application note varies from the setup used to characterize the devices in three aspects

1. DC-link inductance:

The DC-link inductance of the setup used for these test has a value of approximately 35 nH for all modules investigated here in contrast to varying values between 35 nH to 80 nH 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 [2].

2. Gate voltage:

This Evaluation Board provides a gate voltage of -8 V for turning-off and 16 V for turning-on whereas characterization is done with a driver providing +/- 15 V of gate voltage.

3. Gate driver output impedance:

According to IEC 60747-9 for characterization of an IGBT the driver used should resemble 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. Gate resistor values have been chosen so that di/dt at turn-on is comparable to characterization conditions. Nevertheless small deviations in the turn-on losses persist.

#### 4.1 Turn-on losses

The turn-on losses are expected to correspond to the datasheet values of the modules. As an example the measured turn-on losses for an EconoDUAL™ 3 FF450R12ME3 are shown in Figure 14.

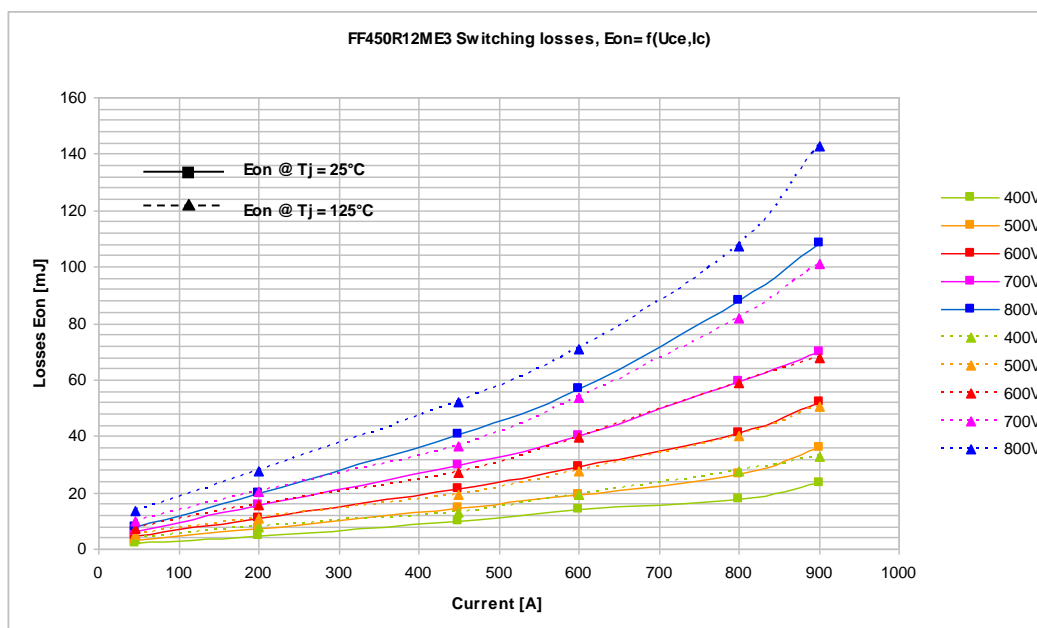
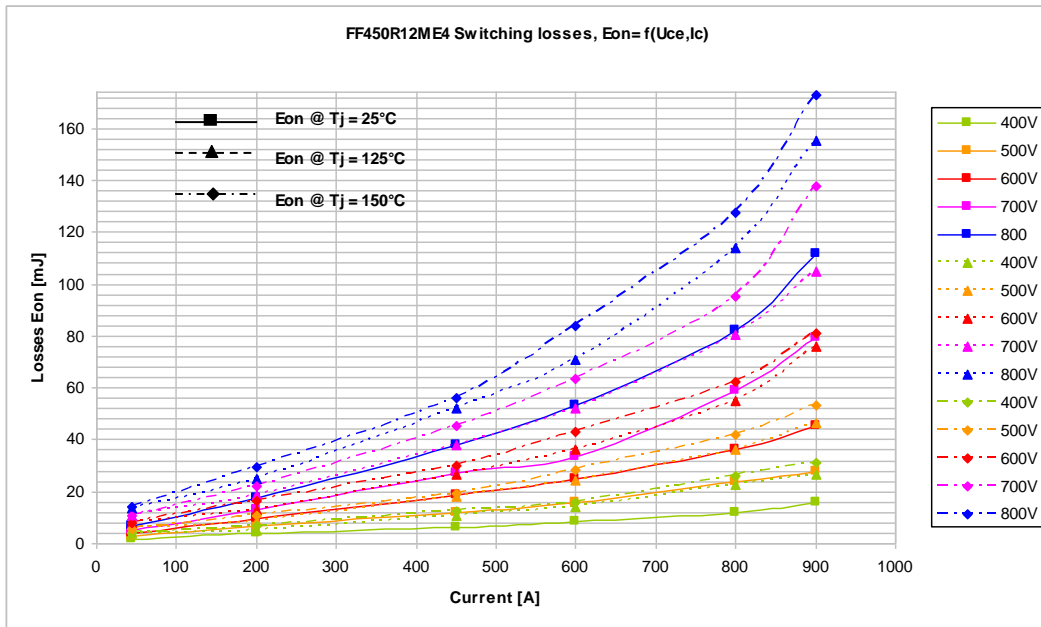


Figure 14 Turn-on losses of a FF450R12ME3 measured using the 2ED100E12-F2

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

The 2ED100E12-F2 is designed to also work on IGBT4-modules as well. Figure 15 depicts the turn-on losses of a FF450R12ME4 module as an example.



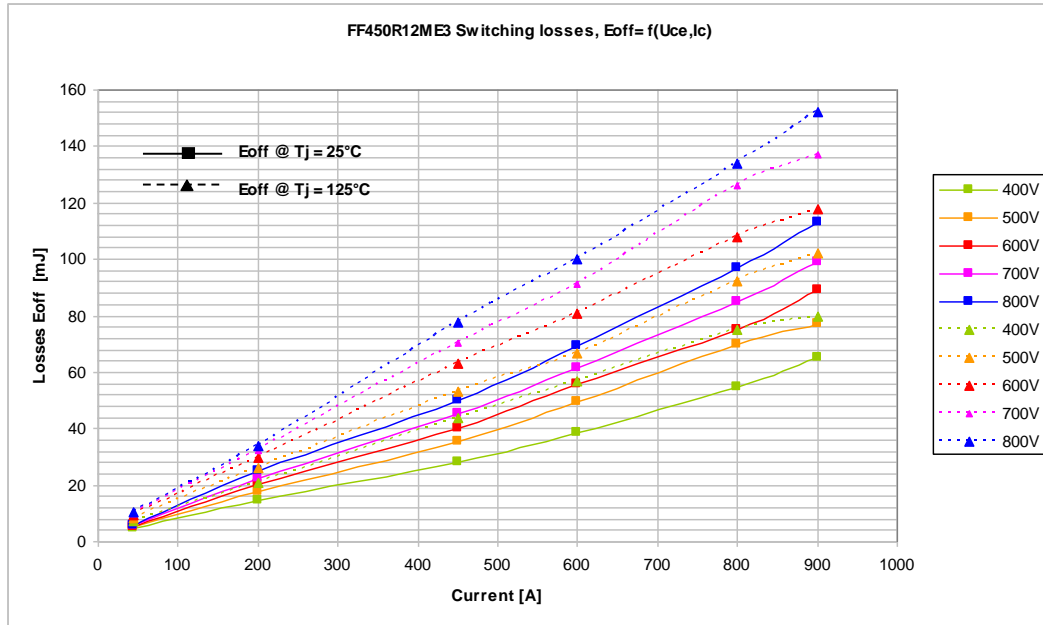
**Figure 15** Turn-on losses of a FF450R12ME4 measured using the 2ED100E12-F2



## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

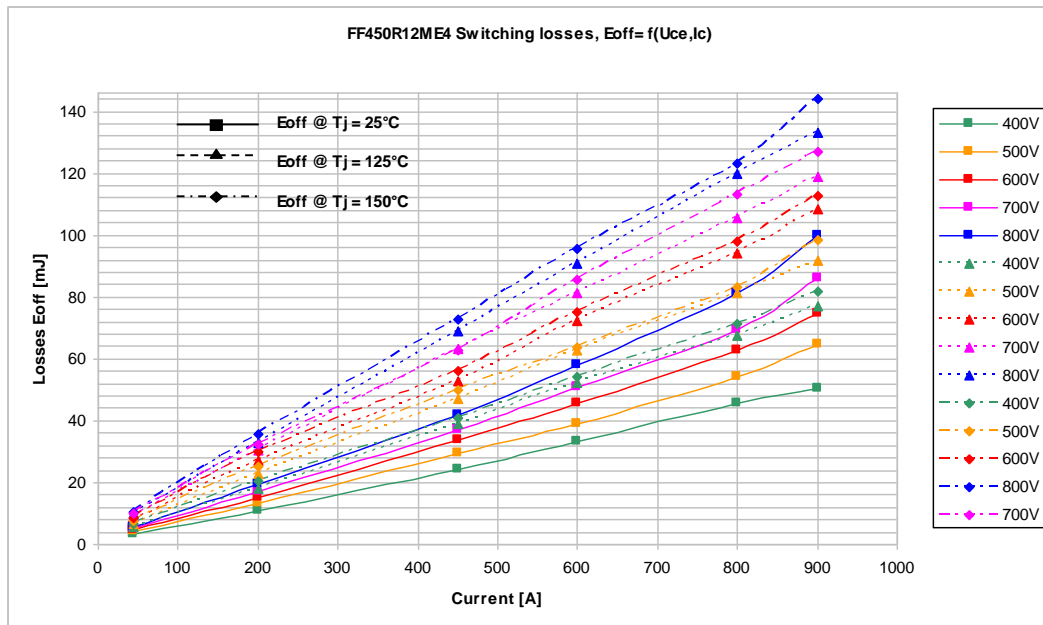
### 4.2 Turn-off losses

In general the turn-off losses linearly increase with the DC-Link voltage. The following Figure 16 and Figure 17 confirm these characteristics and show the dependencies of the measured turning-off losses vs. the DC-link voltage and the current.



a)

Figure 16 Turn-off losses with FF450R12ME3 module



b)

Figure 17 Turn-off losses with FF450R12ME4 module

All losses are measured according to the IEC 60747-9 standard.

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 5 Schematic, Layout and Bill of Material - EconoDUAL™ 3 board

Both driver boards were made by keeping the following rules for the copper thickness and the space between different layers as shown in Figure 18.

Layers:

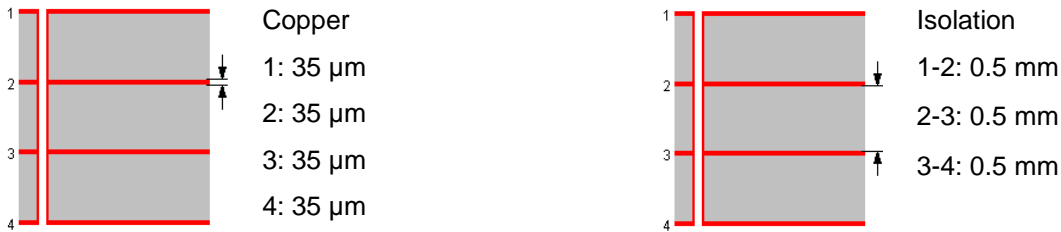


Figure 18 Copper and isolation used

#### 5.1 Schematic

To meet the individual customer requirements and make the Evaluation Driver Board for the EconoDUAL™ 3 module simple for development or modification, all necessary technical data like schematic, layout and components are included in this chapter.

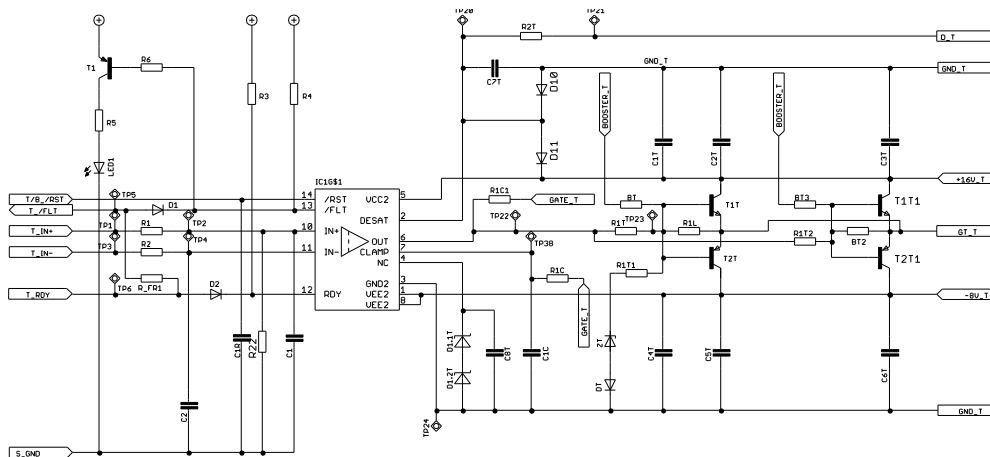


Figure 19 High side IGBT driver

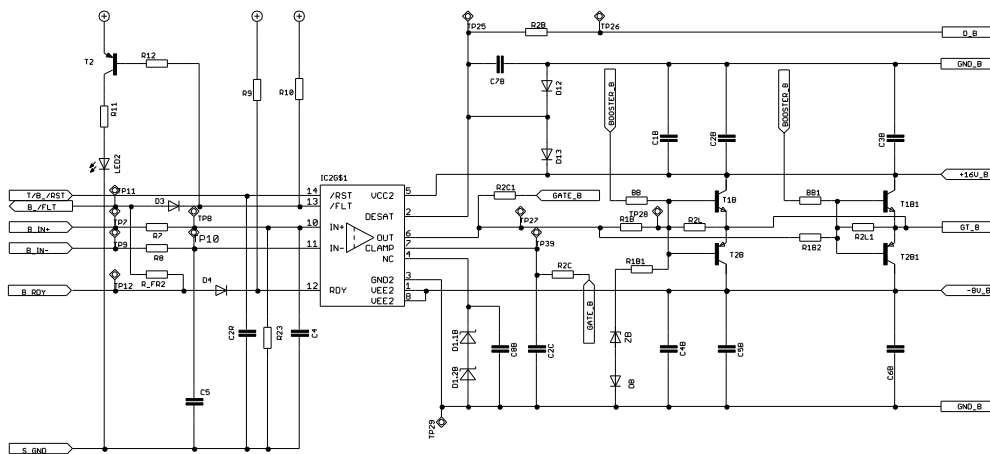


Figure 20 Low side IGBT driver

# Driver Boards for EconoDUAL™ 3 and EconoPACK™+

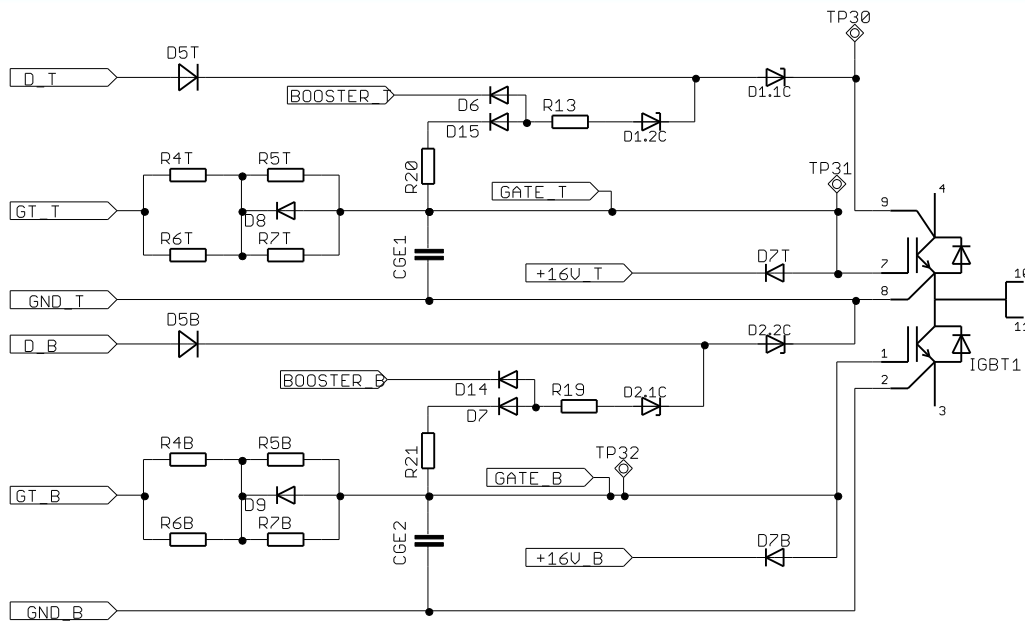


Figure 21 High and Low side IGBT driver output

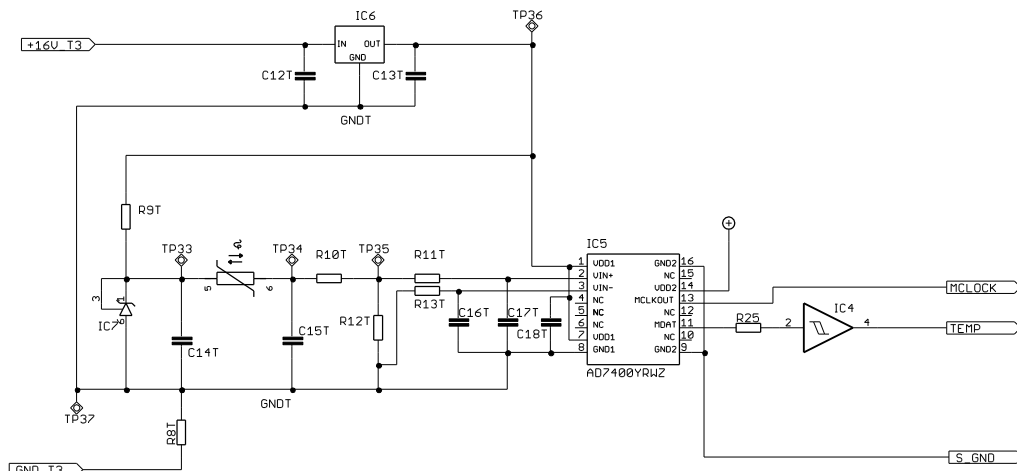


Figure 22 Temperature measurement

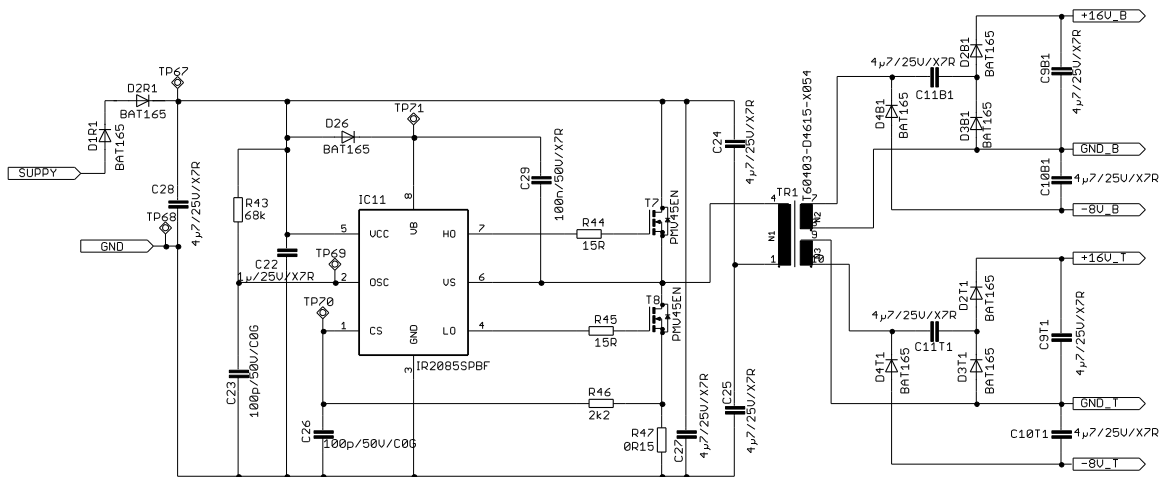


Figure 23 DC/DC converter

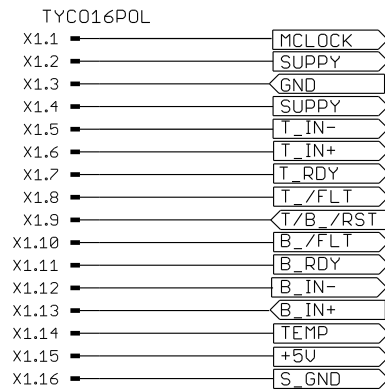


Figure 24 External connector

## 5.2 Assembly drawing

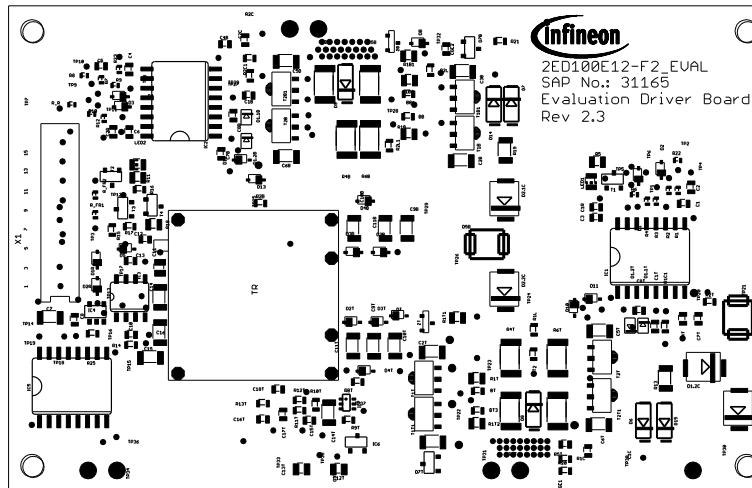


Figure 25 Assembly drawing of the EconoDUAL™ 3 driver board

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 5.3 Layout

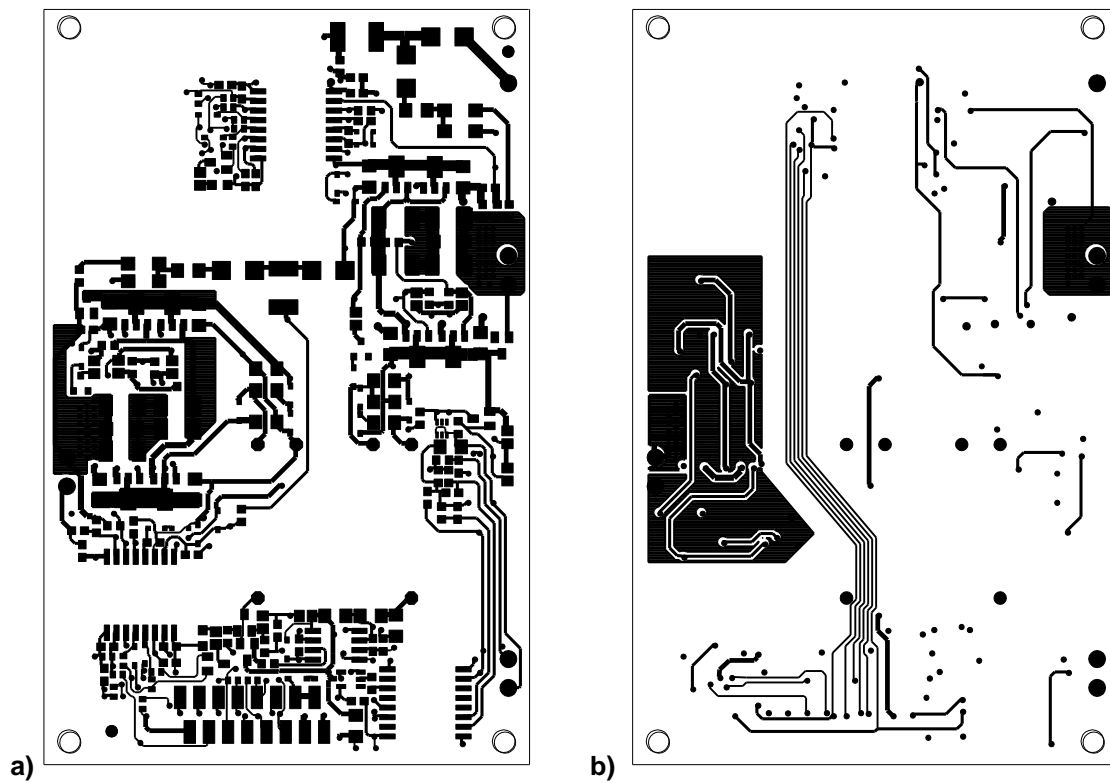


Figure 26 EconoDUAL™ 3 IGBT driver – a) Top layer and b) Layer 2

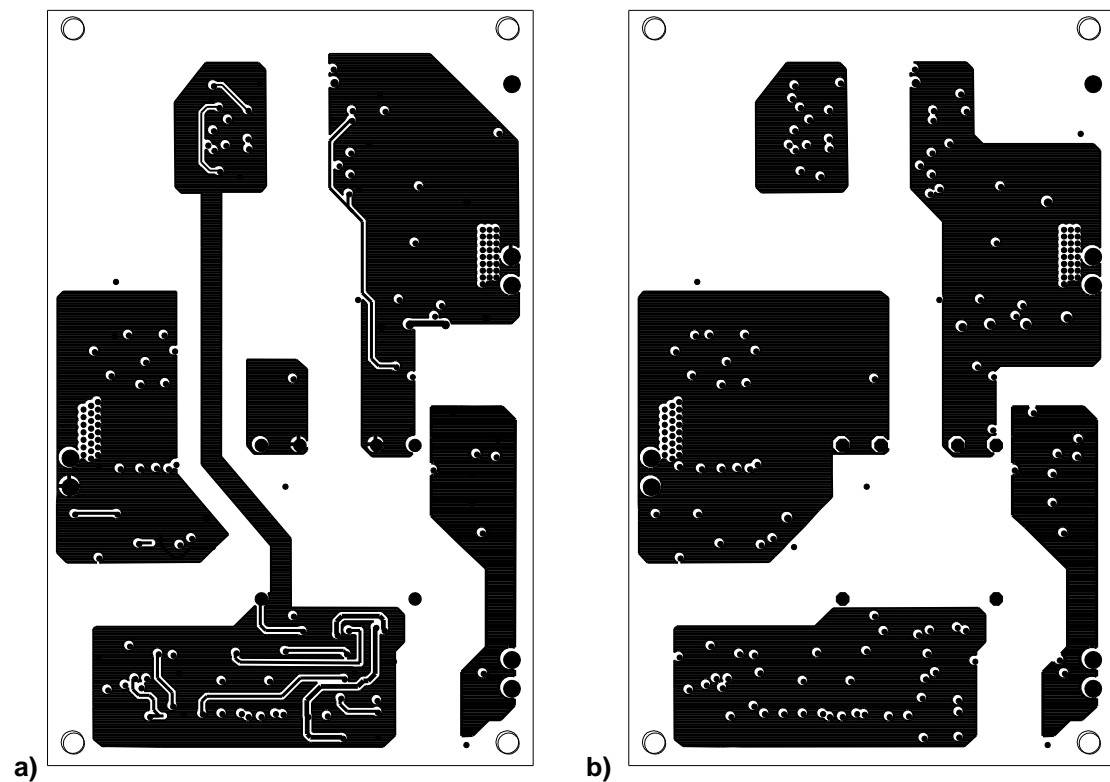


Figure 27 EconoDUAL™ 3 IGBT driver – a) Layer 3 and b) Bottom layer

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 5.4 Bill of Material

The bill of material includes a part list as well as assembly notes. The external gate resistors are not assembled, a list for the resistor values is presented in chapter 6.5.

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 Bill of Material for EconoDUAL™ 3 Driver Board**

| Type                           | Qty | Value / Device    | Package size imperial | Part Name  | Recommended Manufacturer    | Assembled | Description  |
|--------------------------------|-----|-------------------|-----------------------|--|-----------------------------|-----------|--------------|
| Capacitor                      | 4   | 100p/50V/C0G      | C0603                 | C1,C4,C10,C12  |                             |           |              |
| Capacitor                      | 9   | 100n/50V/X7R      | C0603                 | C1B, C1T, C4B, C4T, C3, C6, C8, C13, C18T  |                             |           |              |
| Capacitor                      | 2   | .../50V/C0G       | C0603                 | C1C,C2C  |                             | no        |              |
| Capacitor                      | 2   | 470p/50V/X7R      | C0603                 | C1R,C2R  |                             |           |              |
| Capacitor                      | 5   | 10n/50V/X7R       | C0603                 | C2, C5, C15T, C16T, C17T   |                             |           |              |
| Capacitor                      | 19  | 4 $\mu$ 7/25V/X7R | C-EUC1206             | C2B, C2T, C3B, C3T,C5B,C5T, C6B, C6T,C9B, C9T, C10B, C10T, C11B, C11T, C14T, C7, C14, C15, C16 | Murata                      |           |              |
| Capacitor                      | 2   | 220p/50V/C0G      | C0603                 | C7B,C7T  |                             |           |              |
| Capacitor                      | 2   | 33p/50V/C0G       | C0603                 | C8B,C8T  |                             | no        |              |
| Capacitor                      | 3   | 1 $\mu$ 25V/X7R   | C0805                 | C11,C12T,C13T  |                             |           |              |
| Capacitor                      | 2   | optional/50V/C0G  | C0603                 | CGE1,CGE2  |                             |           |              |
| Connector                      | 1   | TYCO16POL         | TYCO16POL             | X1   | TYCO                        | no        |              |
| Diode                          | 2   | STTH112U          | SOD6                  | D5B,D5T  |                             |           |              |
| Diode                          | 4   | ES1D              | DO214AC               | D6,D7,D8,D9  |                             |           |              |
| Diode                          | 2   | ZLLS1000          | SOT23                 | D7B,D7T  |                             |           |              |
| Driver IC                      | 2   | 1ED020112-F       | P-DSO-16              | IC1,IC2  | Infineon                    |           |              |
| Half-Bridge Driver IC          | 1   | IR2085SPBF        | SO08                  | IC3  | International Rectifier     |           |              |
| Schottky Diode                 | 2   | BAT165            | SOD323R               | DB,DT  | Infineon                    | no        |              |
| Isolated Sigma-Delta Modulator | 1   | AD7400YRWZ        | P-DSO-16              | IC5  |                             |           |              |
| LED                            | 2   |                   | CHIP-LED0805          | LED1, LED2   |                             |           |              |
| Resistor                       | 4   | 27R               | R0603                 | BB, BT, BB1, BT3   |                             |           |              |
| Resistor                       | 4   | 10R               | R0603                 | BT2,R1L,R2L,R2L1   |                             | no        |              |
| Resistor                       | 4   | 100R              | R0402                 | R1,R2,R7,R8  |                             |           |              |
| Resistor                       | 4   | 12R               | R0805                 | R1B,R1T,R1B2,R1T2  | Vishay / CRCW080512R0FKEAHP |           | Pulsresistor |

# Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

| Type               | Qty | Value / Device        | Package size imperial | Part Name  | Recommended Manufacturer | Assembled | Description  |
|--------------------|-----|-----------------------|-----------------------|--|--------------------------|-----------|--------------|
| Resistor           | 2   | 220R                  | R0805                 | R1B1,R1T1  |                          | no        |              |
| Resistor           | 5   | 0R                    | R0603                 | R1C,R1C1,R2C,R2C1,R8T  |                          | no        |              |
| Resistor           | 2   | 0R                    | R0402                 | R_FR1,R_FR2  |                          |           |              |
| Resistor           | 2   | 1k                    | R0603                 | R2B,R2T  |                          |           |              |
| Resistor           | 5   | 4k7                   | R0402                 | R3,R4,R9,R10,R_R   |                          |           |              |
| Resistor           | 2   | 4R7                   | R0603                 | R20,R21  |                          |           |              |
| Resistor           | 4   | 10k                   | R0402                 | R6,R12,R22,R23   |                          |           |              |
| Resistor           | 2   | 39R                   | R0805                 | R5,R11   |                          |           |              |
| Resistor           | 8   | variable              | R2010                 | R4B, R4T, R5B, R5T, R6B, R6T, R7B, R7T   | TT electronics           | no        | Pulsresistor |
| Resistor           | 1   | 1k2                   | R0603                 | R9T  |                          |           |              |
| Resistor           | 1   | 820R                  | R0603                 | R10T   |                          |           |              |
| Resistor           | 3   | 2k2                   | R0603                 | R11T,R13T,R17  |                          |           |              |
| Resistor           | 1   | 270R                  | R0603                 | R12T   |                          |           |              |
| Resistor           | 2   | 10R                   | R1206                 | R13,R19  |                          |           |              |
| Resistor           | 2   | 15R                   | R0603                 | R15,R16  |                          |           |              |
| Resistor           | 1   | 68k                   | R0603                 | R14  |                          |           |              |
| Resistor           | 1   | 0R15                  | R0805                 | R18  |                          |           |              |
| Resistor           | 1   | 39k                   | R0603                 | R25  |                          |           |              |
| Schmitt-Trigger    | 1   | SN74LVC1G17D<br>BVR   | SOT23-5               | IC4  |                          |           |              |
| Schottky Diode     | 17  | BAT165                | SOD323R               | D2B,D2R,D2T,D3,<br>D3B,D3T,D4,D4B,<br>D4T,D5,D10,D11,<br>D12,D13,D1,<br>D1R,D2 | Infineon                 |           |              |
| Shunt Regulator    | 1   | TLV431BIDCKT          | SC70-6L               | IC7  |                          |           |              |
| Transformer        | 1   | T60403-D4615-<br>X054 | D4615-<br>X054        | TR   | Vacuum-<br>schmelze      |           |              |
| Transistor         | 2   | BC856                 | SOT23                 | T1,T2  | Infineon                 |           |              |
| Transistor         | 4   | ZXTN2010Z             | SOT89                 | T1B, T1B1, T1T, T1T1   | Diodes                   |           |              |
| Transistor         | 4   | ZXTP2012Z             | SOT89                 | T2B, T2B1, T2T, T2T1   | Diodes                   | 1         |              |
| TrenchMOS          | 2   | PMV45EN               | SOT23                 | T3,T4  | philips                  |           |              |
| Unipolar TVS Diode | 2   | P6SMB440A             | SMB                   | D1.1C,D2.1C  | Vishay                   |           |              |
| Unipolar TVS Diode | 2   | P6SMB510A             | SMB                   | D2.1C,D2.2C  | Vishay                   |           |              |
| Zener diode        | 4   | MM3Z5V6T1G            | SOD323-R              | D1.1B, D1.1T,<br>D1.2B, D1.2T  | On<br>Semiconductor      | no        |              |
| Voltage regulator  | 1   | ZMR500FTA             | SOT23                 | IC6  |                          |           |              |
| Zener diode        | 2   | BZX84-C11             | SOT23                 | ZB,ZT  |                          | no        |              |

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 5.5 Gate resistor list

**Table 5** External gate resistors  $R_{Gext}$ , all packages are 2010 types

| Module       | $R_{Gon}$ [ $\Omega$ ] | $R_{Goff}$ [ $\Omega$ ] | R4T, R4B, R6T,<br>R6B [ $\Omega$ ] | R5T, R5B, R7T,<br>R7B [ $\Omega$ ] | Assembled |
|--------------|------------------------|-------------------------|------------------------------------|------------------------------------|-----------|
| FF150R12ME3G | 5.6                    | 3,7                     | 7,5                                | 3,7                                | no        |
| FF150R12MS4  | 5.1                    | 3,2                     | 6,2                                | 4                                  | no        |
| FF225R12MS4  | 3                      | 1,5                     | 3                                  | 3                                  | no        |
| FF225R12ME3  | 1.5                    | 0                       | 0                                  | 3                                  | no        |
| FF225R12ME4  | 0                      | 0                       | 0                                  | 0                                  | no        |
| FF300R12ME3  | 1.1                    | 0                       | 0                                  | 2,2                                | no        |
| FF300R12ME4  | 0                      | 0                       | 0                                  | 0                                  | no        |
| FF300R12MS4  | 1.5                    | 0,5                     | 1                                  | 2                                  | No        |
| FF450R12ME3  | 1                      | 0,25                    | 0,5                                | 1,5                                | no        |
| FF450R12ME4  | 1                      | 0                       | 0                                  | 2                                  | no        |
| FF600R06ME3  | 2.0                    | 1,25                    | 2,5                                | 1,5                                | No        |
| FF600R12ME4  | 1.5                    | 0,6                     | 2,5                                | 1,5                                | No        |



## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 6 Schematic, Layout and Bill of Material - EconoPACK™ + board

To meet the individual customer requirements and to ease the development or modification using the Evaluation Driver Board for the EconoPACK™ + module, all necessary technical data like schematic, layout and components are included in this chapter.

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  $\pm 10\%$ .

#### 6.1 Schematic

For the EconoDUAL™ 3 and EconoPACK™ + evaluation boards, the high and low side driver schematics including their power supplies are similar for all half bridges. Therefore it is sufficient to depict only the schematic of the EconoDUAL™ 3.

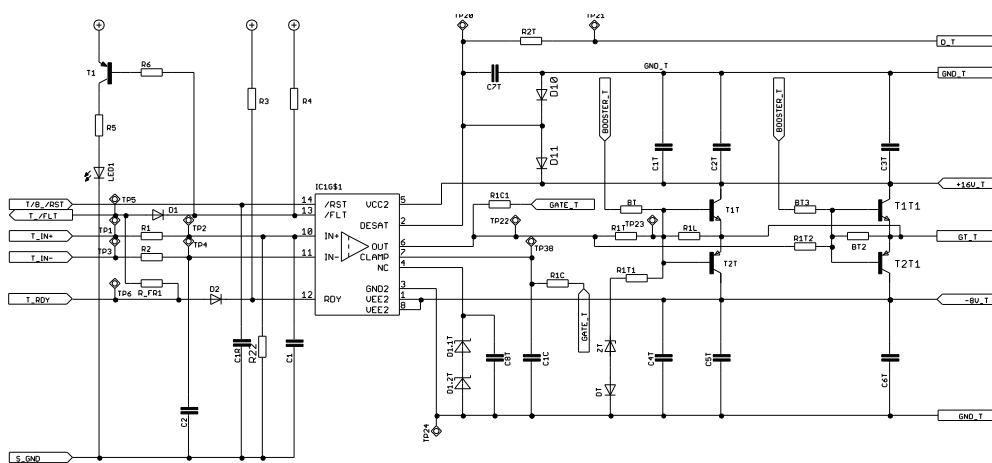


Figure 28 High side IGBT driver

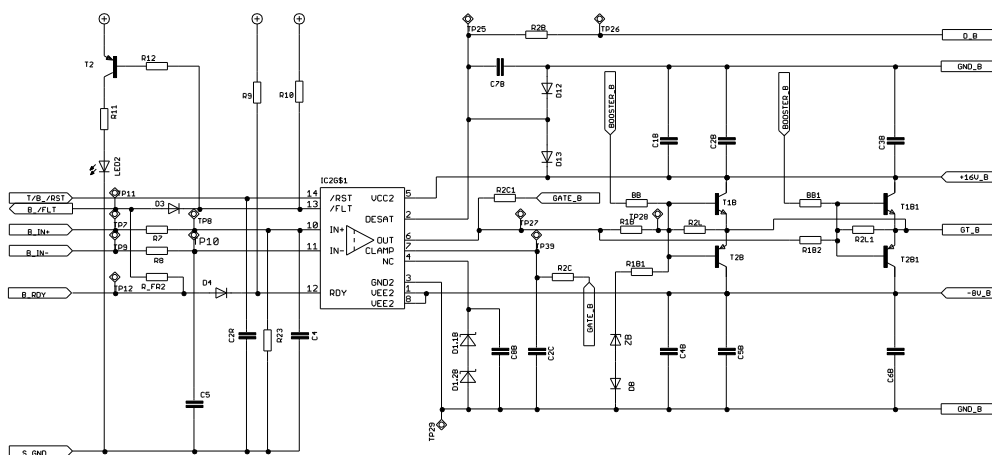


Figure 29 Low side IGBT driver

# Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

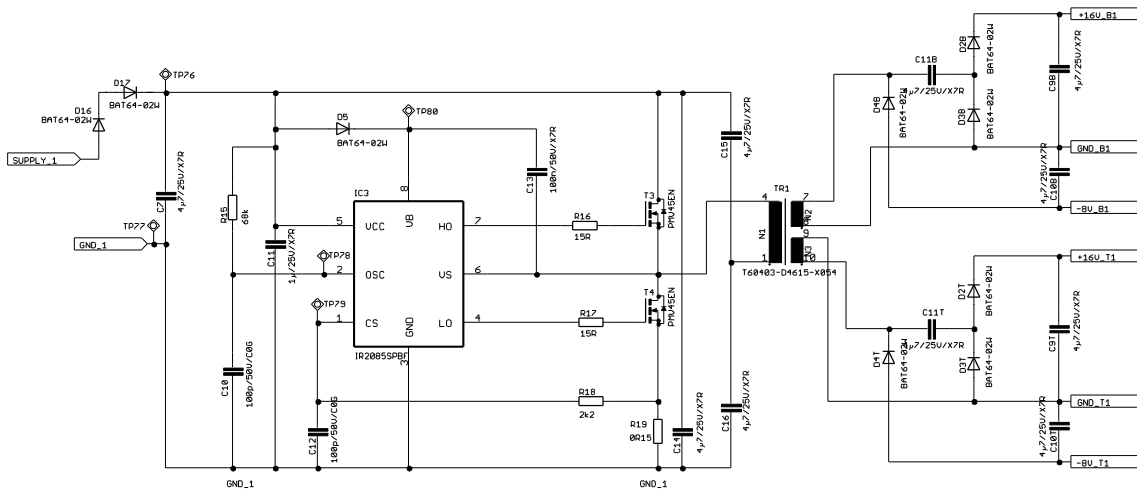


Figure 30 DC/DC converter

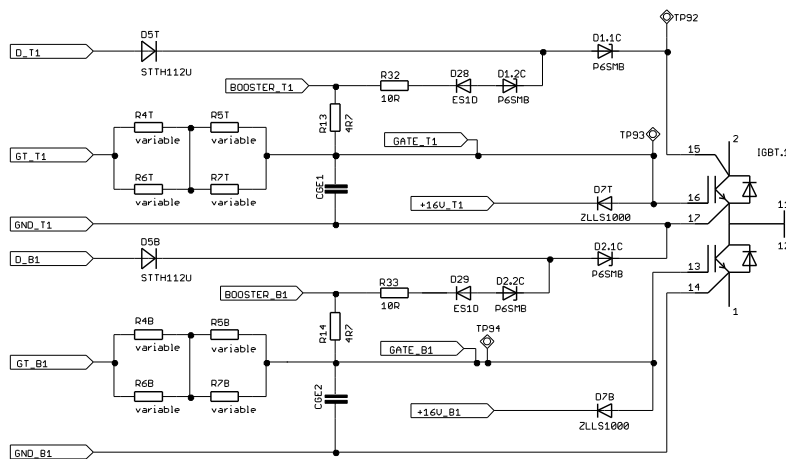


Figure 31 High and Low side IGBT driver output

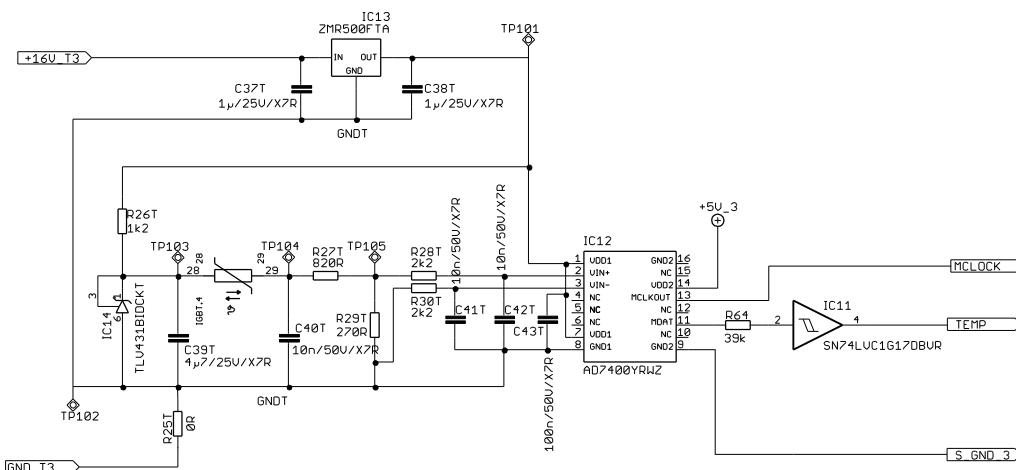


Figure 32 Temperature measurement

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

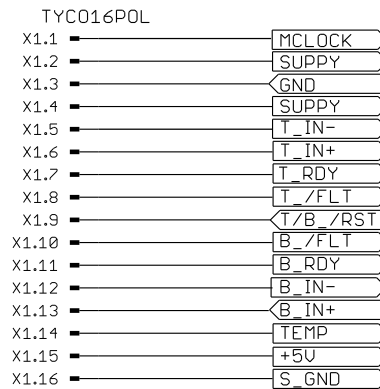


Figure 33 Connector

### 6.2 Assembly drawing

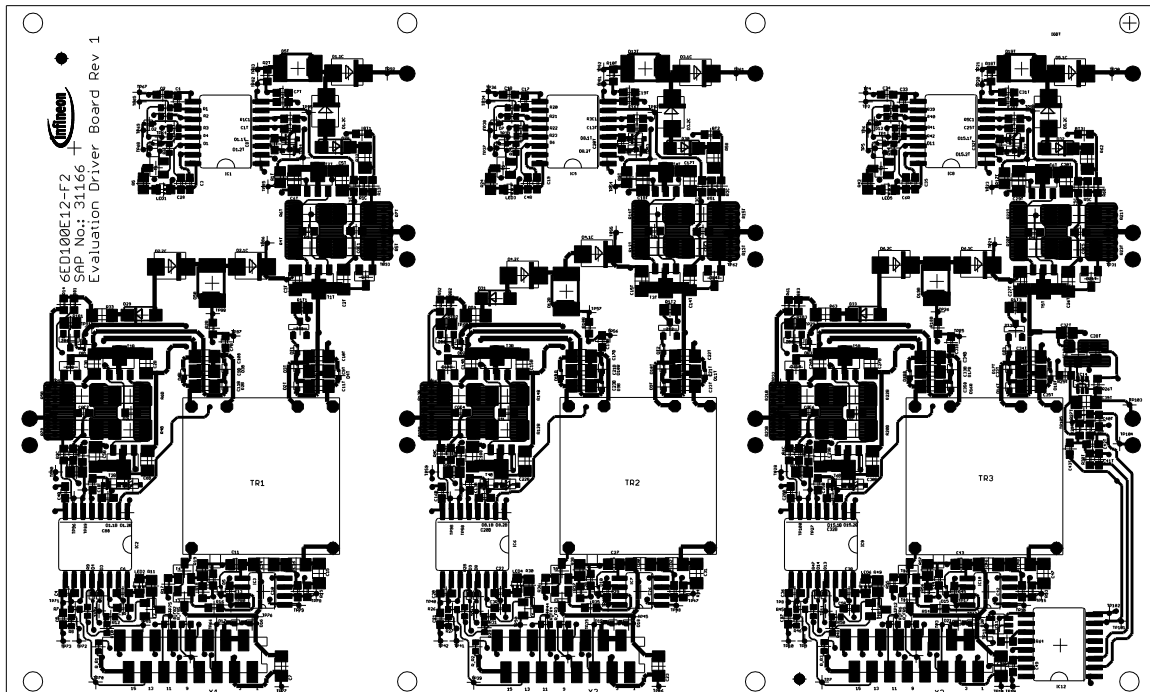


Figure 34 Assembly drawing of the EconoPACK™ + driver board

For detailed information use the zoom function of your PDF viewer.

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 6.3 Layout

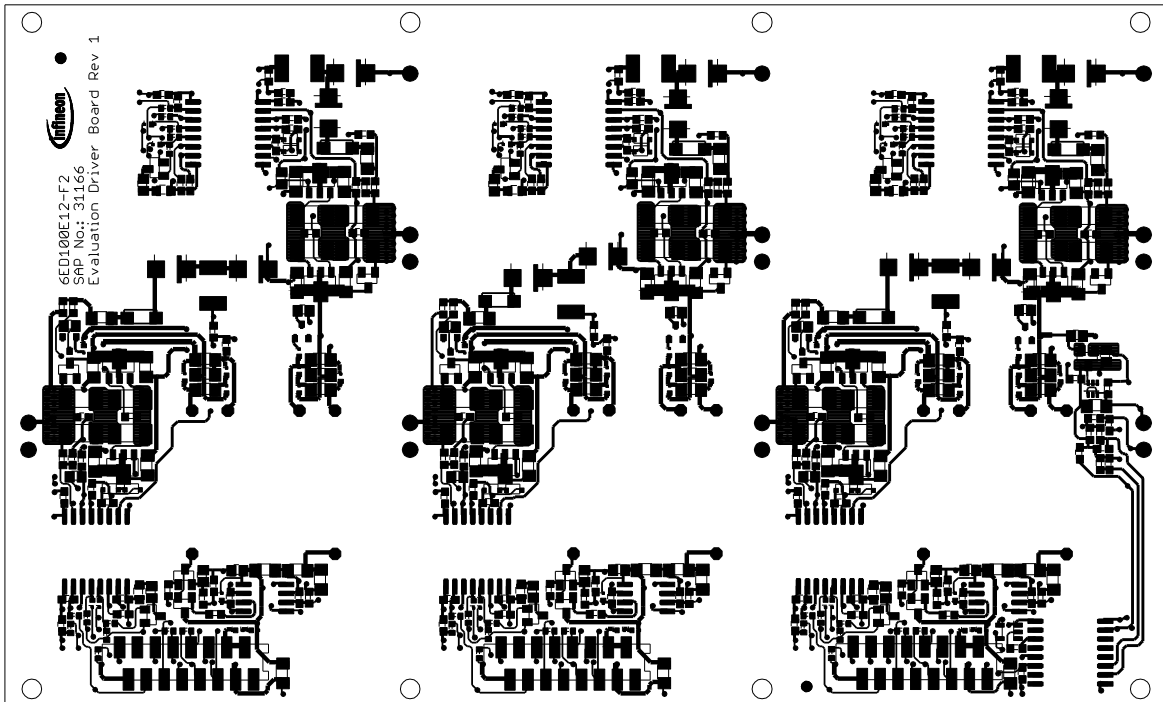


Figure 35 EconoPACK™ + IGBT driver – Top layer

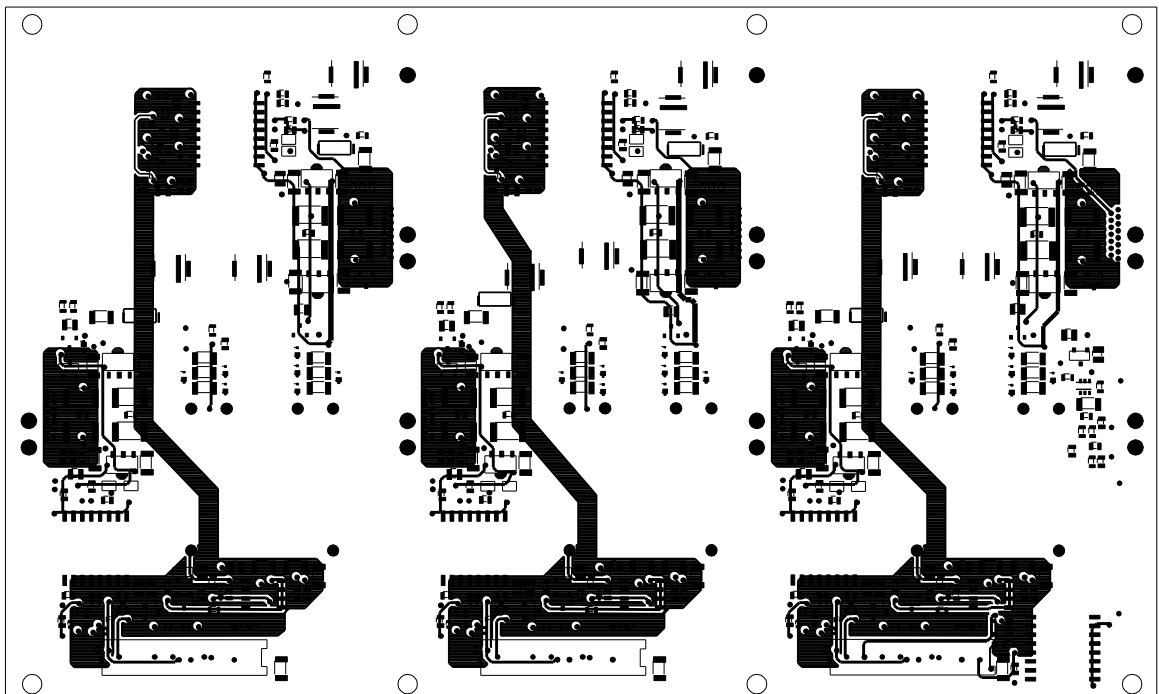


Figure 36 EconoPACK™ + IGBT driver – Layer 2

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

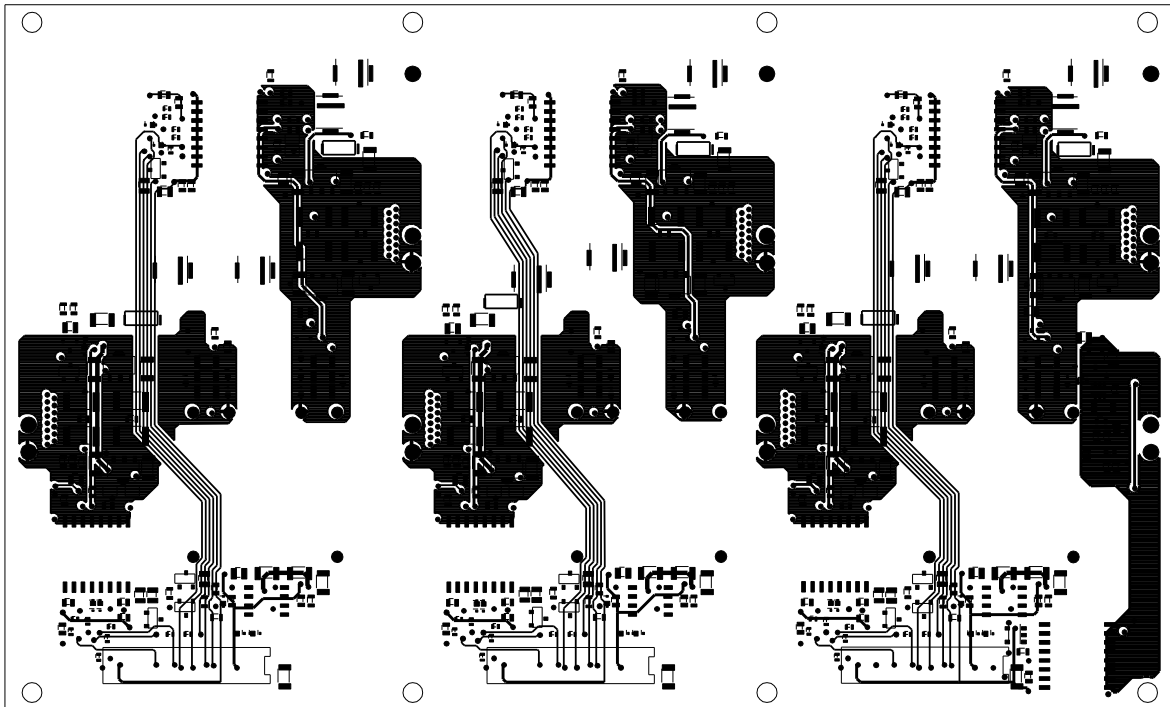


Figure 37 EconoPACK™ + IGBT driver – Layer 3

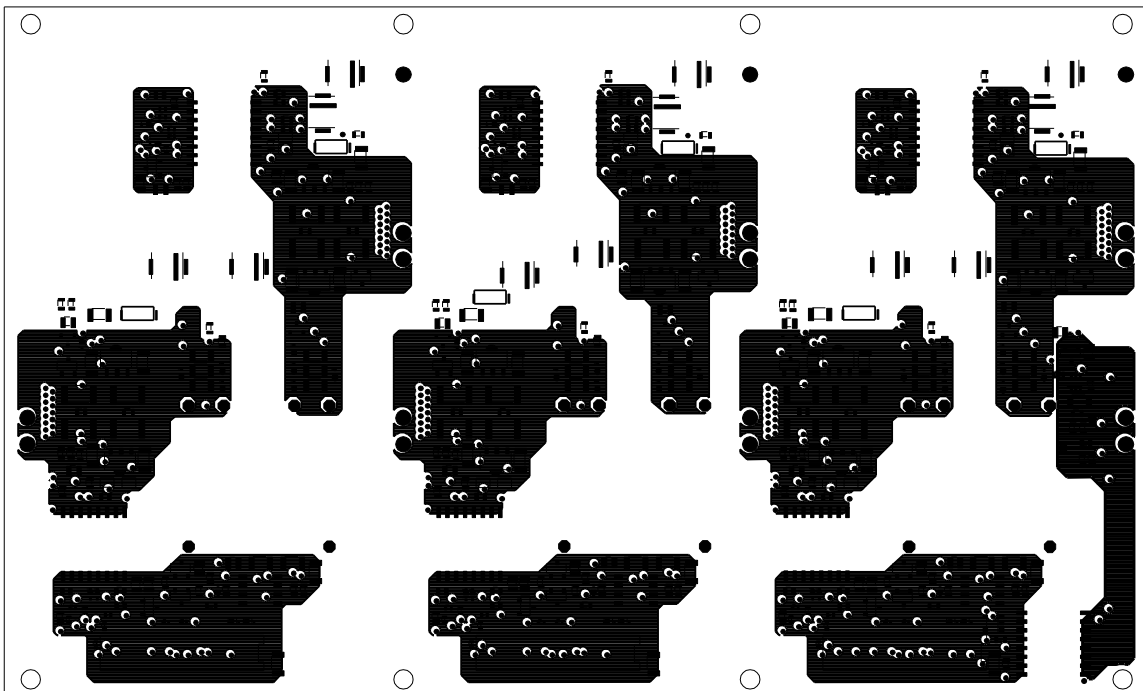


Figure 38 EconoPACK™ + IGBT driver – Bottom Layer 4

## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

### 6.4 Bill of material

The bill of material includes a part list as well as assembly notes. The external gate resistors are not assembled, a list for the resistor values is presented in Table 7 on page 33.

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 6 Bill of Material for EconoPACK™ + Driver Board**

| Type        | Qty | Value / Device    | Package size imperial | Part Name   | Recommended Manufacturer | Assembled |
|-------------|-----|-------------------|-----------------------|---|--------------------------|-----------|
| Capacitor   | 6   | .../50V/C0G       | C0603                 | C1C, C2C, C3C, C4C, C5C, C6C  |                          | no        |
| Capacitor   | 9   | 10n/50V/X7R       | C0603                 | C2, C5, C18, C21, C34, C37, C40T, C41T, C42T  |                          |           |
| Capacitor   | 6   | 33p/50V/C0G       | C0603                 | C8B, C8T, C20B, C20T, C32B, C32T  |                          | no        |
| Capacitor   | 23  | 100n/50V/X7R      | C0603                 | C1B, C1T, C3, C4B, C4T, C6, C13, C13B, C13T, C16B, C16T, C19, C22, C25B, C25T, C28B, C28T, C29, C35, C38, C43T, C45, C49  |                          |           |
| Capacitor   | 12  | 100p/50V/C0G      | C0603                 | C1, C4, C10, C12, C17, C20, C26, C28, C33, C36, C42, C44  |                          |           |
| Capacitor   | 6   | 220p/50V/C0G      | C0603                 | C7B, C7T, C19B, C19T, C31B, C31T  |                          |           |
| Capacitor   | 6   | 470p/50V/X7R      | C0603                 | C1R, C2R, C3R, C4R, C5R, C6R  |                          |           |
| Capacitor   | 6   | optional/50V/C0G  | C0603                 | CGE1, CGE2, CGE3, CGE4, CGE5, CGE6  |                          | no        |
| Capacitor   | 5   | 1 $\mu$ /25V/X7R  | C0805                 | C11, C27, C37T, C38T, C43   |                          |           |
| Capacitor   | 55  | 4 $\mu$ 7/25V/X7R | C1206                 | C2B, C2T, C3B, C3T, C5B, C5T, C6B, C6T, C7, C9B, C9T, C10B, C10T, C11B, C11T, C14, C14B, C14T, C15, C15B, C15T, C16, C17B, C17T, C18B, C18T, C21B, C21T, C22B, C22T, C23, C23B, C23T, C26B, C26T, C27B, C27T, C29B, C29T, C30, C30B, C30T, C31, C32, C33B, C33T, C34B, C34T, C35B, C35T, C39, C39T, C46, C47, C48 | Murata                   |           |
| Transformer | 3   | T60403-D4615-X054 | D4615-X054            | TR1, TR2, TR3   | Vacuum-schmelze          |           |

# Driver Board for EconoDUAL™3 and EconoPACK™+

| Type                           | Qty | Value / Device      | Package size imperial | Part Name  | Recommended Manufacturer | Assembled |
|--------------------------------|-----|---------------------|-----------------------|--|--------------------------|-----------|
| LED                            | 6   | LEDCHIP-            | LED0805               | LED1, LED2, LED3, LED4,<br>LED5, LED6  |                          |           |
| Schottky Diodes                | 39  | BAT64-02W           | SCD80                 | D1, D2, D2B, D2T, D3, D3B,<br>D3T, D4, D4B, D4T, D5, D6, D7,<br>D8, D9, D9B, D9T, D10, D10B,<br>D10T, D11, D11B, D11T, D12,<br>D13, D14, D15, D16, D16B,<br>D16T, D17, D17B, D17T, D18,<br>D18B, D18T, D19, D20, D21 | Infineon                 |           |
| Rectifier Diode                | 6   | ES1D                | DO214AC               | D28, D29, D30, D31, D32, D33   |                          |           |
| Diode                          | 6   | BAT64-02W           | SCD80                 | DB1, DB2, DB3, DT1, DT2, DT3   | Infineon                 | no        |
| Unipolar TVS Diode             | 6   | P6SMB/440V          | SMB                   | D1.1C, D2.1C, D3.1C, D4.1C,<br>D5.1C, D6.1C,   |                          |           |
| Unipolar TVS Diode             | 6   | P6SMB/510V          | SMB                   | D1.2C, D2.2C, D3.2C, D4.2C,<br>D5.2C, D6.2C  |                          |           |
| Diode                          | 6   | STTA112U            | SOD6                  | D5B, D5T, D12B, D12T, D19B,<br>D19T  |                          |           |
| Zener Diode                    | 12  | MM3Z5V6T1G          | SOD323-R              | D1.1B, D1.1T, D1.2B, D1.2T,<br>D8.1B, D8.1T, D8.2B, D8.2T,<br>D15.1B, D15.1T, D15.2B,<br>D15.2T  | On Semiconductor         | no        |
| Zener Diode                    | 6   | BZX84-C11           | SOT23                 | ZB1, ZB2, ZB3, ZT1, ZT2, ZT3   |                          | no        |
| Diode                          | 6   | ZLLS1000            | SOT23                 | D7B, D7T, D14B, D14T, D21B,<br>D21T  | Diodes                   |           |
| Driver IC                      | 6   | 1ED020112-F         | P-DSO-16              | IC1, IC2, IC5, IC6, IC8, IC9   |                          |           |
| Half-Bridge Driver             | 3   | IR2085SPBF          | SO08                  | IC3, IC7, IC10   | International Rectifier  |           |
| Schmitt-Trigger                | 1   | SN74LVC1G17DBV<br>R | SOT23-5               | IC11   |                          |           |
| Isolated Sigma-Delta Modulator | 1   | AD7400YRWZ          | P-DSO-16              | IC12   | Analog Devices           |           |
| Voltage regulator              | 1   | ZMR500FTA           | SOT23                 | IC13   |                          |           |
| Shunt Regulator                | 1   | TLV431BIDCKT        | SC70-6L               | IC14   |                          |           |

## Driver Boards for EconoDUAL™3 and EconoPACK™+

| Type     | Qty | Value / Device | Package size imperial | Part Name  | Recommended Manufacturer | Assembled          |
|----------|-----|----------------|-----------------------|--|--------------------------|--------------------|
| Resistor | 6   | 0R             | R0402                 | R_FR1, R_FR2, R_FR3,<br>R_FR4, R_FR5, R_FR6  |                          |                    |
| Resistor | 15  | 4k7            | R0402                 | R_R1, R_R2, R_R3, R3, R4, R9,<br>R10, R22, R23, R28, R29, R41,<br>R42, R47, R48  |                          |                    |
| Resistor | 6   | 10k            | R0402                 | R6, R12, R25, R31, R44, R50  |                          |                    |
| Resistor | 12  | 100R           | R0402                 | R1, R2, R7, R8, R20, R21, R26,<br>R27, R39, R40, R45, R46  |                          |                    |
| Resistor | 6   | 0R             | R0603                 | R1C1, R2C1, R3C1, R4C1,<br>R5C1, R6C1  |                          | no                 |
| Resistor | 6   | 27R            | R0603                 | BB1, BB2, BB3, BT1, BT2, BT3   |                          |                    |
| Resistor | 6   | 1k             | R0603                 | R2B, R2T, R10B, R10T, R18B,<br>R18T  |                          |                    |
| Resistor | 1   | 1k2            | R0603                 | R26T   |                          |                    |
| Resistor | 5   | 2k2            | R0603                 | R18, R28T, R30T, R37, R56  |                          |                    |
| Resistor | 6   | 4R7            | R0603                 | R13, R14, R51, R52, R60, R61   |                          |                    |
| Resistor | 6   | 10R            | R0603                 | R1L, R2L, R3L, R4L, R5L, R6L   |                          | no                 |
| Resistor | 6   | 15R            | R0603                 | R16, R17, R35, R36, R54, R55   |                          |                    |
| Resistor | 1   | 39k            | R0603                 | R64  |                          |                    |
| Resistor | 3   | 68k            | R0603                 | R15, R34, R53  |                          |                    |
| Resistor | 1   | 270R           | R0603                 | R29T   |                          |                    |
| Resistor | 1   | 820R           | R0603                 | R27T   |                          |                    |
| Resistor | 3   | 0R15           | R0805                 | R19, R38, R57  |                          |                    |
| Resistor | 7   | 0R             | R0603                 | R1C, R2C, R3C, R4C, R5C,<br>R6C, R25T  |                          | no                 |
| Resistor | 6   | 12R            | R0805                 | R1B, R1T, R9B, R9T, R17B,<br>R17T  |                          |                    |
| Resistor | 6   | 39R            | R0805                 | R5, R11, R24, R30, R43, R49  |                          |                    |
| Resistor | 6   | 220R           | R0805                 | R1B1, R1B2, R1B3, R1T1,<br>R1T2, R1T3  |                          | no                 |
| Resistor | 6   | 10R            | R1206                 | R32, R33, R58, R59, R62, R63   |                          |                    |
| Resistor | 24  | variable       | R2010                 | R4B, R4T, R5B, R5T, R6B, R6T,<br>R7B, R7T, R12B, R12T, R13B,<br>R13T, R14B, R14T, R15B,<br>R15T, R20B, R20T, R21B,<br>R21T, R22B, R22T, R23B, R23T | TT electronics           | no: See<br>Table 8 |



## Driver Boards for EconoDUAL™ 3 and EconoPACK™ +

| Type       | Qty | Value / Device | Package size imperial | Part Name                    | Recommended Manufacturer | Assembled |
|------------|-----|----------------|-----------------------|------------------------------|--------------------------|-----------|
| Transistor | 6   | BC856          | SOT23                 | T1, T2, T5, T6, T9, T10      |                          |           |
| TrenchMOS  | 6   | PMV45EN        | SOT23                 | T3, T4, T7, T8, T11, T12     | Philips                  |           |
| Transistor | 6   | ZXTN2010Z      | SOT89                 | T1B, T1T, T3B, T3T, T5B, T5T | Diodes                   |           |
| Transistor | 6   | ZXTP2012Z      | SOT89                 | T2B, T2T, T4B, T4T, T6B, T6T | Diodes                   |           |
| Connector  | 3   | 8-188275-6     | 16POL                 | X1, X2, X3                   | Tyco                     |           |

### 6.5 Gate resistor list

**Table 7** External gate resistors  $R_{Gext}$  are listed below, all packages are 2010 types

| Module       | $R_{Gext}$ [ $\Omega$ ] | R4T, R4B, R6T, R6B<br>R12T, R12B, R14T, R14B<br>R20T, R20B, R22T, R22B [ $\Omega$ ] | R5T, R5B, R7T, R7B<br>R13T, R13B, R15T, R15B<br>R21T, R21B, R23T, R23B [ $\Omega$ ] |
|--------------|-------------------------|---|---|
| FS150R12KE3G | 8.2                     | 5.6   | 5.6   |
| FS225R12KE3  | 3.3                     | 1.5   | 1.5   |
| FS300R12KE3  | 2.4                     | 1.1   | 1.1   |
| FS450R12KE3  | 1.6                     | 1   | 1   |

## 7 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 Infineons 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 EconoDUAL™ 3 Evaluation Driver Board: 31165

IFX order number for EconoPACK™ + Evaluation driver board: 31166

## 8 References

[1] Infineon Technologies AG, AN2007-04, 'How to calculate and to minimize the dead time requirement for IGBTs properly', V1.0, May 2007, [www.infineon.com](http://www.infineon.com)

[2] Bäßler, M., Ciliox A., Kanschä P., 'On the loss – softness trade-off: Are different chip versions needed for softness improvement?' PCIM Europe 2009, Nuremberg, May 2009