eupec IGBT **EiceDRIVER**
IGBT Driver for medium and high power IGBT Modules

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Abstract
While considering technical high-quality IGBT drive circuits, a team worked out the basic features of driver core 2ED30C17.
This driver core is suitable for voltages up to 1700V at an extremely high isolation stability and peak currents of 30A. By applying various features (e.g. DVRC Dynamic Voltage Rise Control), this driver core is designed for IGBT3 and also for the highly-proven NPT technology.
Based on the construction of this intelligent driver core, the driver is suitable for various IGBT module designs. By help of an additional carrier hardware, it can be adapted to EconoPACK+, 62mm, and IHM.
By this flexible design, it is possible to drive IGBT modules from 150A to 2400A and voltages of 1200V and 1700V at switching frequencies up to 30 kHz. Extensive protection measures and an integrated fault management render safe operating possible, even under the circumstances of rough, noise-sensitive industrial environment.

General information

The IGBT driver is the link between the power electronics and the control electronics. In this connection, we do not simply talk about the mere turn-on and turn-off of a gate voltage. To cope with the complex switching behaviour in combination with the required protection functions for IGBT`s and the control unit, is a feature that characterises a good IGBT driver. Especially with regard to applications of the medium and high power range further features like high noise immunity, fast switching, and protection circuits are absolutely necessary.
On the world-wide market, besides eupec, there are other manufacturers who offer IGBT modules of various voltages, currents, and topologies. There is, however, hardly any supplier of high quality IGBT drivers. eupec GmbH wants to bridge this gap and wants to offer full solutions with regard to intelligent driving units for IGBTs in the medium and high power range to its customers.

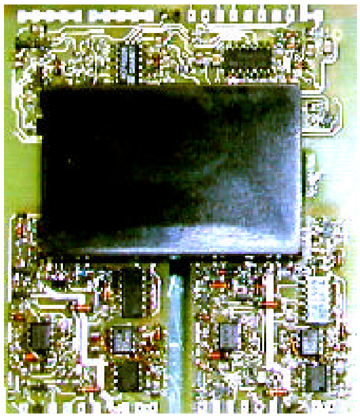


Figure1. Dual driver core: ***EiceDriver 2*ED30C17**

Target description

Concluded from the requirements of the user, the features of such an IGBT driver for the mentioned power range, can be defined easily. One feature is the noise immunity mentioned earlier. It normally results from a circuit design that fulfils the EMC-requirements. Additionally, however, a low coupling capacitance of the existing transformers and the consistent use of sufficiently high signal levels are of significant importance. A minimum pulse control logic which suppresses short noise pulses completes the EMC-safety of the driving circuit.

Additional target requirements are the detection and signalling of IGBT over-currents and short-circuit currents and the undervoltage monitoring of the supply voltages. With regard to half bridge operations, the individual channels have to be safely interlocked against each other, while adhering to a dead time.
To cut a long matter short: A compact and cost-effective driver which guarantees a high system reliability and which is of good availability as exclusively "second source" parts are used. This eupec IGBT ***EiceDRIVER*** (***E****upec* ***I****GBT* ***C****ontrol* ***E****fficient* ***DRIVER***) will be described in detail in the following.

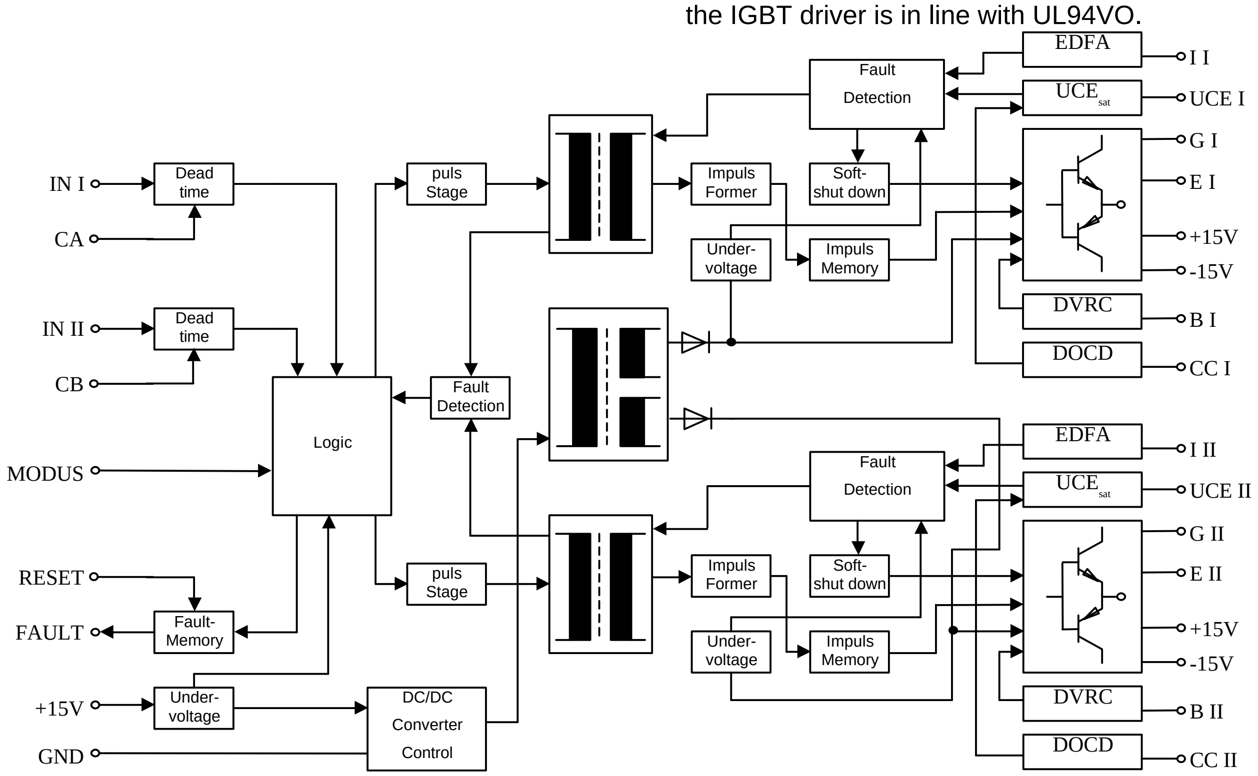
Functional characteristics

While considering the functional characteristics of one channel of the dual IGBT driver core, one has to make a distinction between the primary and the secondary side. Pulse transformers form the bi-directional interface between the sides, they transmit the trigger pulses and the reported failure signals.
As a second connection link, there is an electrically isolated 2x4W DC-DC converter. It provides the secondary supply voltages and by its high efficiency it is able to drive up to 3 IGBT modules connected in parallel.
Further functions are:

- Secondary-side:
  - dynamic over-current detection **(DOCD)** by monitoring the saturation voltage;
  - "Soft shut down" in case of failure shutdown;
  - external detected failure analysis **(EDFA)**;
  - undervoltage monitoring +16V
  - 15V logic (high noise immunity)
  - ±16V supply voltage protected against overcurrent
  - dynamic voltage rise control of the turn-off behaviour **(DVRC)**
  - additional ± 16V supply outputs

- Primary-side:
  - failure output
  - half-bridge – or direct mode can be adjusted;
  - interlocking against each other and dead time generation in half-bridge mode
  - low-resistance and therefore noise-immune 15V PWM signal input
  - **+15V signal processing (15V logic)**
  - minimum pulse suppression 400ns
  - reset input and auto reset

While developing the driver core, special attention was paid to the safety aspect.
The air and creepage distances were determined as per specifications EN50178 and UL508c. The flame resistant construction of the IGBT driver is in line with UL94VO.



Electrical features

The IGBT driver core 2ED30C17 was developed for 600V, 1200V, and 1700V applications. The maximum gate peak current I_{Gate} can go up to 30A based on a voltage of V_{GE}=±15V.
The typical output power is 4W per channel.
In order to increase the output power, both channels can be connected in parallel. By this way, even high current IGBT modules can be driven.
Detailed electrical data:

- 4kV insulation voltage
- I_{Gate}=30A
- V_{GE}=±15V
- P=4W per channel
- -40 to +85°C temperature range
- 600ns operating time (400ns minimum pulse + 200ns system operating time)
- failure output 30V 20mA (open collector)
- signal inputs 30V permanent voltage-proof
- +15V supply voltage
- high EMC stability of all inputs
- 1,0 ohm minimum gate resistance

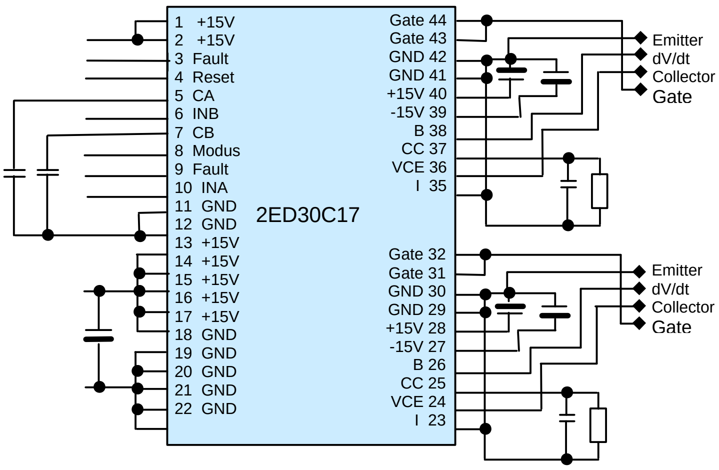


Figure 3: Connecting diagram 2ED30C17

Dynamic overcurrent detection

Each driver channel has got a dynamically adapted V_{CEsat}-monitoring. By this, a rise in the V_{CEsat} voltage in case of a short circuit is detected. While turning on the IGBT modules, in most cases an increased current can be observed for a short time. Therefore the monitoring threshold during turn-on is adapted in a dynamic way as shown in figure 4.

The duration and the response threshold can be adjusted by the user individually by an external R-C circuit.

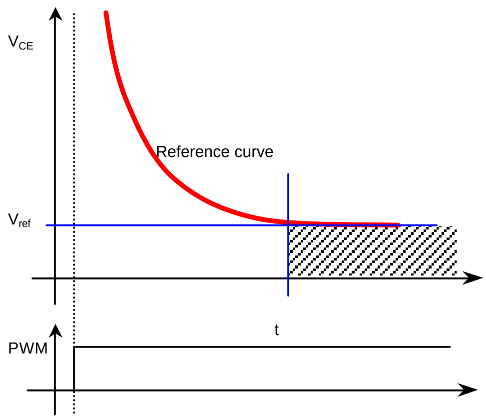


Figure 4: dynamic reference voltage gradient

In case the V_{CE} voltage – while the IGBT is turned on –exceeds the reference curve, the overcurrent monitoring responds and the failure is activated.

"Soft shut down"

In order to avoid inadmissible gate turn-off over-voltages in case of a short circuit, each driver channel is equipped with a soft switch off. It is activated when a failure is detected and initially discharges the gate at a reduced discharge current. After some µs of soft discharge the gate is safely fixed to –15V. This 2-stage switch off by help of an external resistance control can be adapted to the individual module types.

External detected failure analysis (EDFA)

An additional way of activating the failure mode and in this connection the "soft shut down" is given by the external failure input. An applied signal activates the failure mode and turns the driver off. Typical applications in this case could be the detection of heatsink over-temperatures and the overload monitoring by external current transducers.

Dead time generation in half-bridge mode

When operating the dual driver core in half-bridge mode, the two channels are safety interlocked against each other. In addition and in order to avoid a bridge breakthrough, a dead time is generated. The dead time is adjusted for each channel individually by an external C circuit

Undervoltage detection primary and secondary

In order to guarantee o safe logic operation and a safe switching of the IGBTs, the driver core operates with a separate undervoltage monitoring for the primary and the secondary side. Should the primary supply voltage fall below a value of **13 V**, the driver is blocked and a failure signal is generated.
In a similar way the 16V voltage supply of the secondary side is being treated. If a voltage drop of more than **3,5V** is detected, again a failure signal will be generated and transmitted to the primary side. At the same time, the driver blocks and no further IGBT trigger signals will be executed.

Dynamic turn off (DVRC)

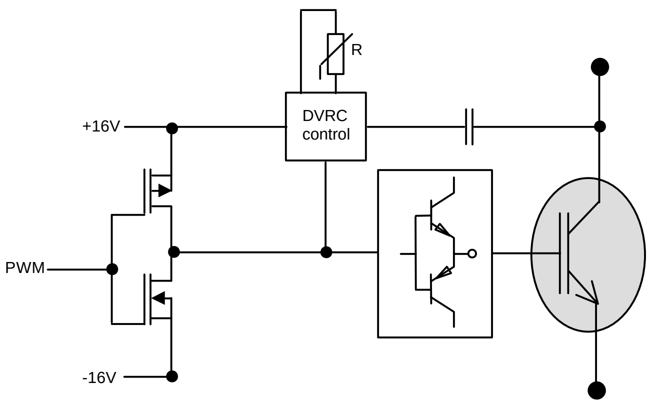


Figure 5: block diagram DVRC

Especially during turn off of IGBT3, it is hardly possible to influence the di/dt and in this connection the dynamic over-voltage by a gate resistor. In order to influence the turn off behaviour, the 2ED30C17 optionally is equipped with DVRC (**D**ynamic **V**oltage **R**ise **C**ontrol).

This circuit allows a direct control of the di/dt during turn off. The di/dt is adjusted via the resistor R (figure 5).

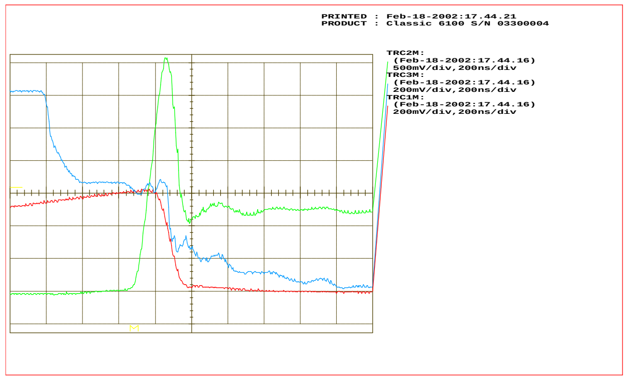


Figure 6: turn off without DVRC by FS450R12KE3

Figures 6 and 7 show the turn off behaviour of EconoPACK+ FS450R12KE3 without/with DVRC. The measuring arrangement was constructed with a leakage inductance of 91nH in order to show the behaviour clearly.

V_{GE} 5V/div.
I_C 200A/div.
V_{CE} 100V/div.

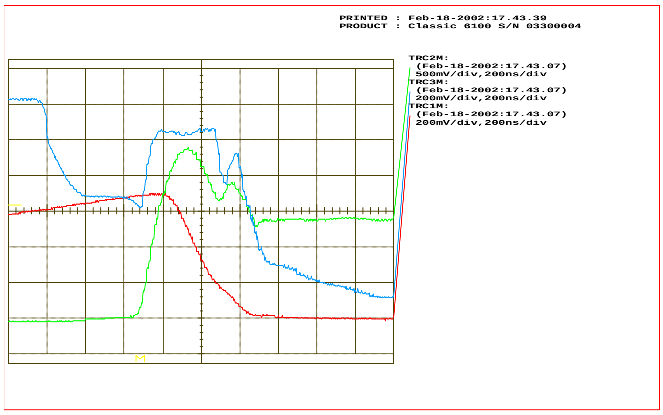


Figure 7: turn off with DVRC by FS450R12KE3

The advantages of this adjustment, i.e. of a lower di/dt, are improved EMC characteristics and certainly a reduction in the turn-off over-voltage as shown in figures 6 and 7. This can be observed mainly in case of an overcurrent or short circuit.
A disadvantage certainly is given by the higher turn-off losses, resulting from the IGBT's slower turn off. An active intervention just in case of a short circuit is equally possible. In such a case, the circuit costs come to 50 % of the costs for active clamping by Z-diodes.

“Core function” the transformer

The centre-pieces of driver core 2ED30C17 are the pulse transmitters and the DC-DC-transformer. Both are designed in such a way that they show a very low coupling capacitance and have a high insulation strength.
The two pulse transmitters and the DC-DC transformer core are located, hermetically sealed, in a flame resistant plastic case.

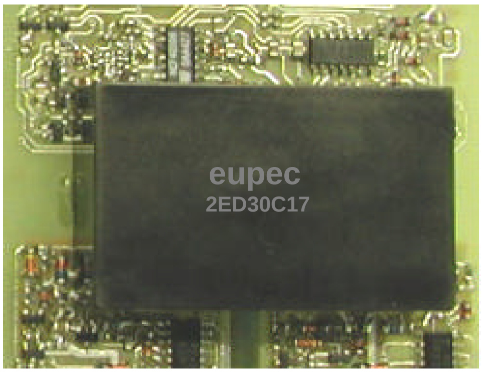


Figure 8: pulse transmitter and DC-DC transformer.

Strictly separated windings and the exclusive use of high-quality insulation material and ferrite lead to an extremely good behaviour of the transmitter.
The pulse transmitter is equipped with low-resistance inputs and outputs and operates at 15V-pulses in order to improve the signal-to-noise ratio.

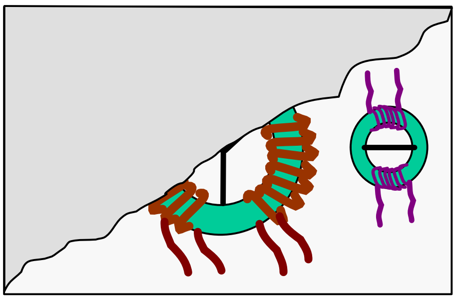


Figure 9: internerl transformer structure

In order to reach its high power density, the DC-DC transformer operates based on the push-pull/flow-through principle. By rectification of the two secondary alternating voltages one achieves the required ±16V. In case of a gate-emitter short circuit the voltage on the primary side would collapse because of high short circuit currents. The complete control of the converter including the other driver channels would fail and this would result in an uncontrolled destruction of the converter. In order to counteract and to avoid an unwanted switching of other IGBTs, the DC-DC outputs are protected against overcurrent.

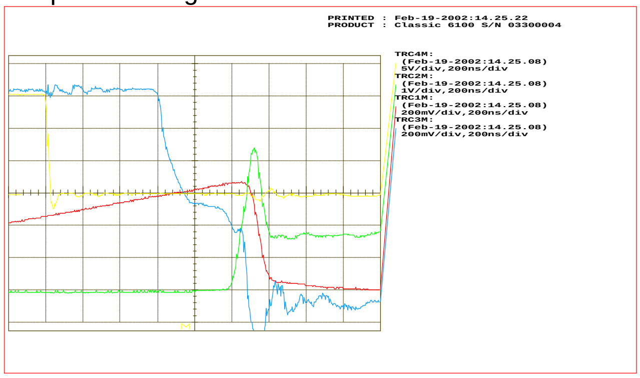


Figure 10: turn off 2ED30C17 with FS450R12KE3

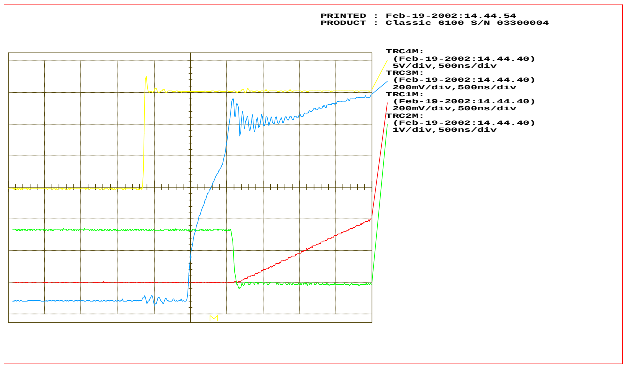


Figure 11: turn on 2ED30C17 with FS450R12KE3

+15V PWM Logik Signal
V_{CE}
I_C
V_{GE}

Application SixPACK driver configuration for EconoPACK+, 62mm, and IHM modules

By using three driver cores 2ED30C17 and additional equipment, eupec presents a sixpack driver, which easily and without much effort can be adapted to existing module concepts.
By the help of so-called “basic boards” this sixpack driver can be adapted to the different module types.

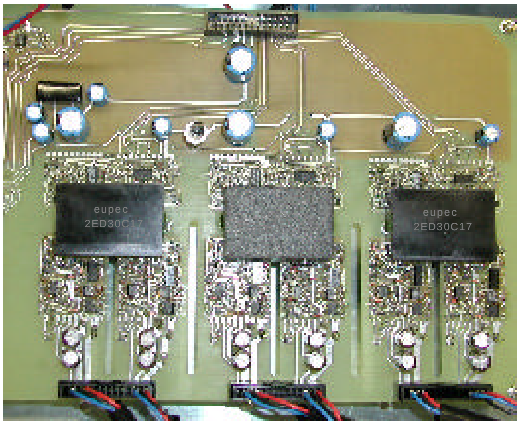


Figure 12: SixPACK EiceDriver

Interface X1 on the primary side (26Pol input plug) is explained by figure (table) 15. The interface – based on potential-free inputs and outputs – allows a direct contacting to the controller.
The outputs for the NTCs inside the module have the base insulation acc. to specification EN50178; the insulation test as per EN50178 is part of the routine test.

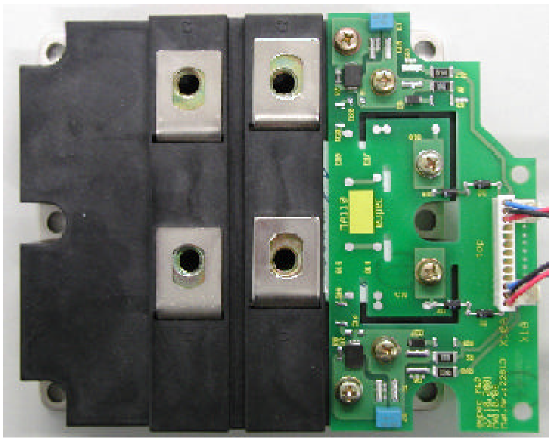


Figure 13: Basic PCB MA110 for IHM FF600R17KF6B2

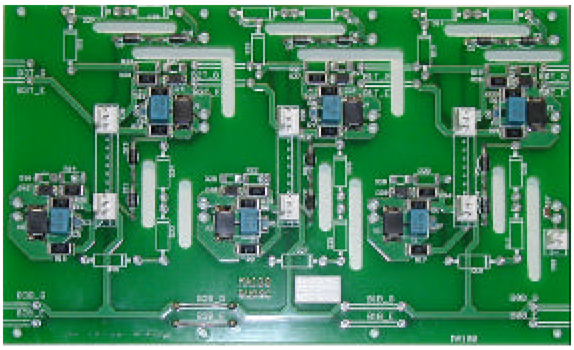


Figure 14: Basic PCB MA110 for EconoPACK+

The "basic boards" MA110 and MA100 are equipped with the so-called "hot components", being gate resistors and gate-emitter clamping diodes.
Optionally, further components such as DVRC and emitter resistors can be added.
MA100 also supports the parallel connection of several half bridges of the EconoPACK+ module.

PIN	Signal	Bemerkung/Comment
1	Screen	internal connection with GND
2	BOT U IN	control signal bottom IGBT U
3	Fault 1	Fault output halfbridge U
4	TOP U IN	control signal top IGBT U
5	Bot V IN	control signal bottom IGBT V
6	Fault 2	Fault output halfbridge V
7	TOP V IN	control signal top IGBT V
8	BOT W IN	control signal bottom IGBT W
9	Fault 3	Fault output halfbridge W
10	TOP W IN	control signal top IGBT W
11	Over Temp.	open collector 30V/15mA
12	Reset	high= reset
13	DC-BUS voltage	external
14	n.c.	reserved for 24V DC-DC input
15	n.c.	
16	+15V	supply voltage +15V±0,5V
17	+15V	supply voltage +15V±0,5V
18	GND	power and signal input
19	GND	power and signal input
20	analog Temp.out	not linearised
21	GND analog	GND for analog outputs
22	I-analog out U	loop through current transducer
23	GND analog	GND for analog outputs
24	I-analog out V	loop through current transducer
25	GND analog	GND for analog outputs
26	I-analog out W	loop through current transducer

Figure 15: X1 pin assignment