Gate Control Unit for IGBT Drive Converters offers IPM Functionality, maintaining Flexibility in System Design

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A driver board is proposed which has been designed as high performance, ready to use interface between controller and power semiconductor module of converter–brake–inverter type for variable speed drive systems.

Integrated circuits are commonly used to drive MOS controlled power transistors [1]. They permit to build drivers with low part count, replacing discrete components. Depending on the particular IC, the remaining external circuitry permits parameter adaptation to achieve an operational behaviour and protection of the power transistors as desirable in the application. As a further step, intelligent power modules — IPM [2] — have been introduced which integrate the complete driver circuit. Their use can be very efficient if the module is well adapted to the system; if this however is not the case, a modification of IPM design usually is only affordable for a high subsequent production volume. In the following, the approach of a driver unit is described which incorporates all required circuitry for controlling and protecting the IGBTs of a typical drive converter according to **figure 1**. The board will be placed beside a standard power semiconductor module. The accessibility of its connections gives the opportunity to still adapt parameters according to the requirements of the system which guarantees useability of the driver unit in a variety of applications. Its design and behaviour are described in the following with special regard to logic interface and power supply — both related to the subject of potential separation —, gate control and protection:

The functional circuit diagram in **figure 2** shows the driver unit with its interface to the controller ($PBM_1 ... \overline{F}$, bottom), its main functional blocks, its connections to external power supplies ($+_1 ... M_{2467}$, right) and its interface

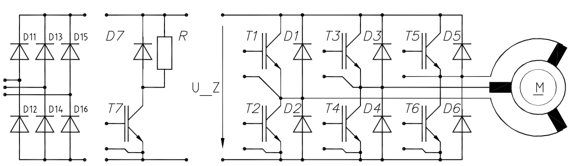

Figure 1: schematic of a power section for an AC drive, consisting of three phase mains rectifier, brake chopper and three phase inverter with IGBTs, feeding an induction or synchronous machine

($wr_+ ... e_7$) through gate resistors ($R_{G1} ... R_{G7}$) to the power semiconductor module ($D_{11} ... D_{16}$, $T_1/D_1 ... T_7/D_7$, top). Physically, the unit has been realised as a compact board with a size of $90mm \cdot 36mm$ as depicted in **figure 3**. The driver functions are effectuated by ICs of revised IXBD4410 type for lower transistors T_2, T_4, T_6, T_7 and of revised IXBD4411 type for upper transistors T_1, T_3, T_5. Prototypes have been built and tested in a $7,5kW$ drive converter connected to $400V$ $3\sim$ with the inverter being operated at a switching frequency up to $25kHz$.

The interface to the controller consists of one input signal $PBM_1 ... PBM_7$ per transistor $T_1 ... T_7$ to determine its switching state. Upper and lower transistors thus can be turned on and off independently; bridge short circuits — undesirable in converters with constant voltage intermediate circuit, the board has been designed for — however are prevented by a cross conduction

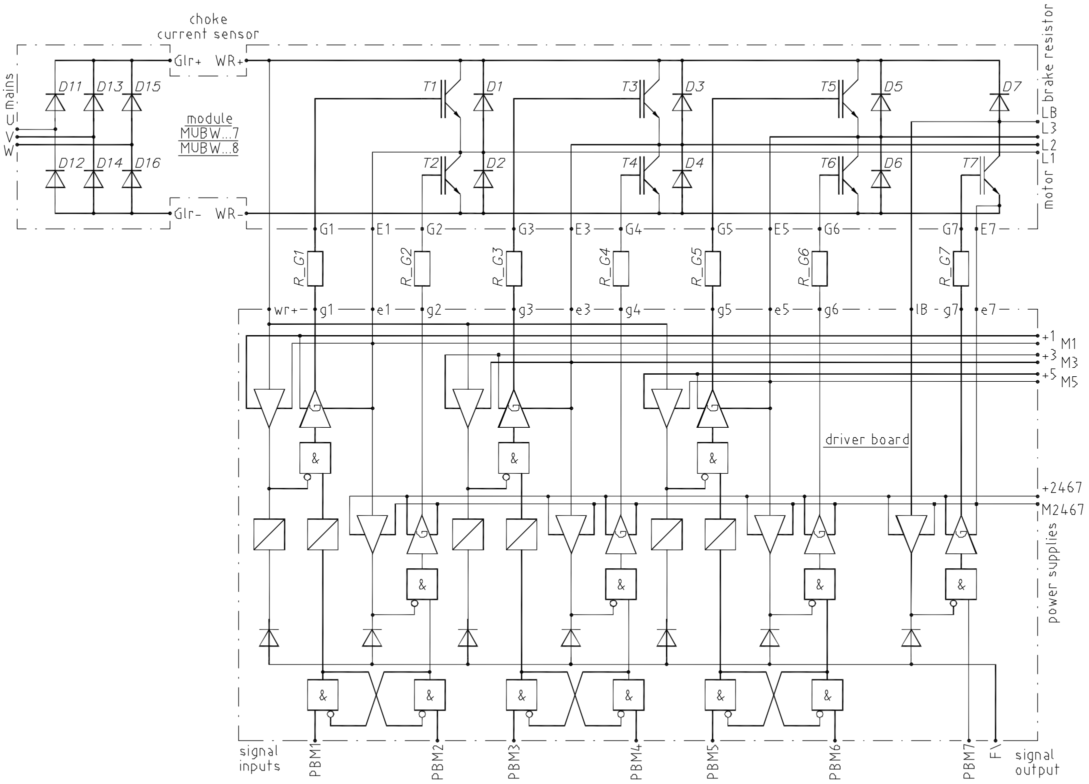

Figure 2: functional circuit diagram of driver circuit and power semiconductor module

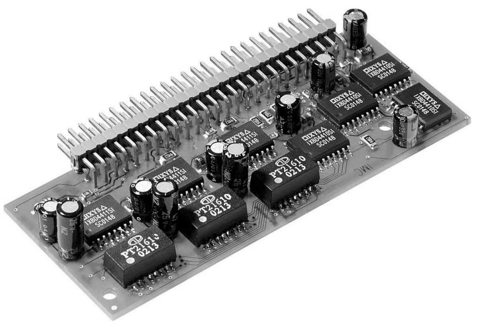

Figure 3: top side of driver board

series connection of a high voltage diode and a current peak limiting resistor each. The capacitors supplying the upper drivers are then charged when the respective lower transistor is in on state and thus closes ground connection. This simple method however only works in a limited range of duty cycles, power-up has to be considered separately and gate voltage levels are met less accurately. Connecting the bootstrap circuit or separate power supplies with sufficient strike and creepage distances to the driver unit is simple, as its pinout in **figure 4** shows: Neighbouring terminals on different high potentials maintain a distance of $3 \cdot 2,54mm$. On the board itself a minimum distance of $2mm$ is provided between the respective conductors.

interlock, symbolised by the "&" gates close to the input terminals. While the interface and the drivers for the lower transistors are ground referenced to minus potential of DC link WR_-, the gates of the upper transistors must be supplied from galvanically isolated ICs. Pulse transformers in surface mount packages as visible in figure 3 are used as potential barriers in the signal paths, symbolised in the functional circuit diagram figure 2. This leads to low coupling capacity and high noise immunity — change rates of more than $|\frac{du}{dt}| > 10\frac{kV}{\mu s}$ have been observed in the positive and negative slope of the voltage between upper emitters E_1, E_3, E_5 and DC link minus WR_- without any negative impact on driver operation.

All ground referenced lower drivers together and each upper driver separately are supplied by unipolar voltage sources with typically $15V$. Power supply of the upper drivers can be effectuated in different ways, depending on system design: If there is a switched mode power supply for the lower drivers and the controller anyway, three additional windings on the same core may be used to power the upper drivers, connecting the rectified outputs to the board's supply terminals $+_1/M_1$, $+_3/M_3$, $+_5/M_5$. This guarantees presence of driver supply after power-up independent from duty cycle, which is thus only limited by minimum pulse width of less than $1\mu s$ transferable through the potential barrier. Alternatively a bootstrap circuit may be used, where the power supply terminals $+_1$, $+_3$, $+_5$ are connected to ground referenced $+_{2467}$ via a

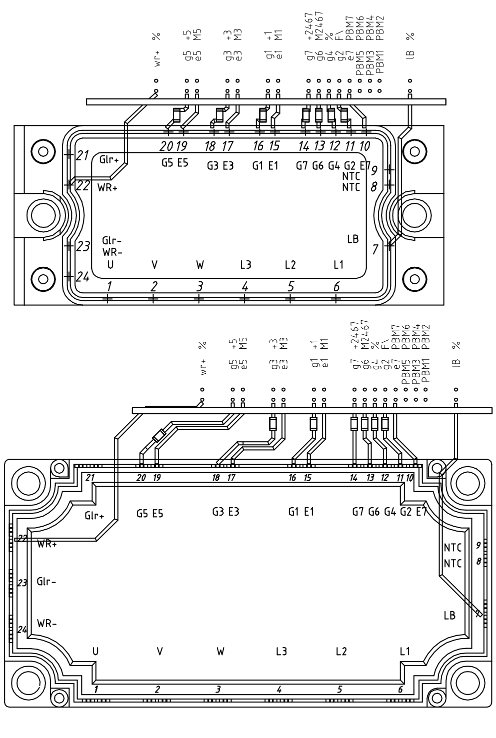

Figure 4: connection scheme between driver board and standard power semiconductor modules of MUBW...7 type (top) and MUBW...8 type (bottom)

The gate drive for the IGBTs supplied by the ICs is of voltage source type: For turn-on, a voltage corresponding to supply voltage — in general $15V$ — is applied between gate and emitter. Turn-off is effectuated with negative voltage: An integrated charge pump provides a level $20V$ below supply voltage — i. e. $-5V$ for a $15V$ supply. This measure helps to minimise the IGBTs' turn-off losses and to properly maintain the transistors in off state also in case of transient disturbances, e. g. caused by snap-off of a free wheeling diode. IGBT switching behaviour should be adjusted applying appropriate gate resistors $R_{G1}...R_{G7}$ in the connections between driver board and power semiconductor module as shown in the schematic figure 2 and the layout proposal with SMD components in figure 4, taking into account IGBT characteristics, requirements of the drive system such as EMC or maximum $\frac{du}{dt}$ and the driver peak output current rating of $2A$. Only small gate resistors of $4,7\Omega$ are provided on the driver board itself, leaving considerable degrees of freedom to a designer implementing the driver unit together with a standard power semiconductor module. If necessary it is of course additionally possible to determine $\frac{di}{dt}$s and $\frac{du}{dt}$s for turn-on and turn-off or protect the gates using a more dedicated gate circuit as shown in **figure 5** for one IGBT.

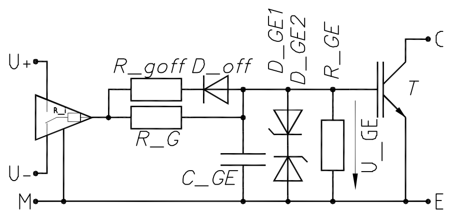

Figure 5: optional additional gate circuitry

Besides aforementioned cross conduction interlock, measures are taken for protection against IGBT overcurrent or short circuit and failure of driver supply which would lead to operation of the power transistors under undefined conditions: In case an IGBT's collector-emitter voltage after turn-on exceeds $10V$, desaturation is assumed and turn-off gate voltage is immediately applied to the respective device. This function is symbolised by the comparators and the "&" gates close to the drivers "G" in figure 2. It should be noted that the voltage dividers required for this function have been sized for converters operating at nominal AC input voltages of up to $400V\ 3\sim$. If desaturation is observed at any transistor, the fault feedback output $\overline{F}$ in the controller interface is pulled to ground. The feedback signals of the upper transistors are led via another potential barrier consisting of a pulse transformer as described above and "or" coupled to the DC link minus WR_- referenced fault output $\overline{F}$, the feedback signals of the lower transistors are directly "or" coupled to as symbolised by the diodes linked to $\overline{F}$ in figure 2. Fault response algorithm is to be implemented in the controller which decides whether the converter shall be shut down or further operated. In case the positive supply voltage falls below $9,5V$ or the negative supply — generated by the charge pump as explained above — gets more positive than $-3V$, the respective driver turns the power transistor off or denies turning it on respectively; further, a fault signal is issued on the open collector output $\overline{F}$ for use by the controller. This measure makes sure that no transistor is operated under gate conditions beyond these limits, which might happen in case of power-up, power-down or failure of auxiliary supply or bootstrap circuit.

It can be concluded that a driver unit with enhanced functionality has been developed. It helps to significantly simplify the design of power sections for variable speed electric drives with $230V$ or $400V$ AC supply, using industry standard IGBT modules; flexibility is provided to adapt operational parameters to system requirements.

References

[1] S. Ochi, N. Zommer: Driving and protecting the latest high voltage and current power MOS and IGBTs; IEEE IAS annual meeting, Houston 1992

[2] M. Hierholzer: IGBT halfbridge with galvanically isolated digital interface; PCIM Conference, Nürnberg 1993