EXPERIENCES WITH A SMART POWER IGBT DRIVER BOARD

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Summary

In modern power electronic converters an interface between the world of information and the world of power is required. Low power level control signals are controlling high power on converter switches. Today a variety of IC drivers exists on the market dedicated for driving IGBTs or MOSFETs. The paper describes main features and experiences in the use of a smart power IGBT driver board. Emphasized are different protection schemes.

Keywords: IGBT driver, overcurrent protection, desaturation protection

1. INTRODUCTION

In modern power electronic converters an interface between the world of information and the world of power is required. Logic commands at 5 V or 15 V voltage level precisely control actions at high voltages and currents (typical power electronic switch deals with up to kV and up to several hundreds Amps). As IGBT and MOSFET are today mostly used semiconductor components used for power electronic switches and have the same structure of the gate circuit, several IC chips are developed to drive their gates. IC chips alone cannot fulfill all the requirements for driving IGBT and MOSFET gates, so “smart” driver boards are build based on IC driver chips with some additional components. The basic aim of this paper is to introduce basic properties of modern IC driver chips and boards as well as to discuss some experiences obtained during testing some smart power IGBT driver boards.

As power electronic switches are used mostly in pairs (upper and lower) because of bridge topology of converter, a driver board should obtain proper isolation between upper and lower part as well as control signal level translation from lower to upper part. Smart driver board should incorporate self shutdown protection circuitry to protect the power switch from overcurrent or short circuit. A fault signal output from driver board should inform control electronics that an error occurred. One of the important requirements is also internal inhibiting of simultaneously turning on both power switches (crossconduction) in one phase leg leading to short circuit.

The paper describes a specific solution of smart driver board DDM-1 (ENERPRO) based around IC driver chipset IXBD4410/4411 (IXYS) used for driving IGBT power module ID2212A2 (POWEREX).

2. MAIN FEATURES OF CHIPSET AND DRIVER BOARD

Fig. 1 shows block diagram of DDM-1 driver board with input and output signals as well as basic functional blocks. There are 5 (6) pins for controls and power supply and 6 pins for driving and sensing on transistor side. Pins for power supply are +15V and GND and eventually CP (charge pump). If there is no need for external power supply for upper side of driver then CP is internally connected with +15V pin. Input control signals for lower and upper transistor are INL and INH (input low and high). Output pin for control logic is FLT (fault) which indicates an erroneous state of driver board or power transistor. Power side pins are E1,G1,C1,E2,G2 and C2. On this pins emitters, gates and collectors of lower and upper power transistors are connected.

Main features of the IC driver chipset and driver board are pointed out next. Most of the features cannot be separated or dedicated only to chipset or board alone so they are listed together.

- 1200 V low to high side isolation with single power supply required. A bootstrap circuit is providing power supply for upper chip. A separate power supply can also be used for upper chip resulting with better driving characteristics.
3. PROTECTION SCHEMES

Logic representation of driver board fault diagnostic is presented on Fig. 2. Fault diagnostic of each chip (4410 - lower or 4411-upper) works separately. When an error occurs in either upper or lower driver part or switch, appropriate gate signals are disabled and FLT (fault) signal is formed for outside use, e.g. to inform control logic that an error occurred. Each driver chip traces following signals: INL/INH (input signal for lower or upper side), over current or desaturation, under-voltage of $V_{DD}$ (positive supply voltage) and under-voltage of $V_{EE}$ (negative supply voltage). Overcurrent or desaturation error causes latching of fault signal, but under-voltage fault condition is only sustained until the power supply voltages are restored. Internal chip fault signals are reset on the next rising edge of input signal so it is

3.1. Overcurrent/Desaturation Detection Circuit

Described driver board (chipset) provides a very flexible overcurrent/desaturation protection capability that works with both standard 3-terminal power transistors as well as with 4- or 5- terminal current sensing power devices. Protection principle is presented on Fig. 3 and 4.

Each IC driver chip has $I_m$ input with trip threshold $V_{Ainh}$ centered at 250 mV respectively to KG input. It is practically a smart comparator which compares voltages between $I_m$ and KG terminals when input signal is “ON” and which input is shorted when input signal is “OFF”. A capacitor $C_x$ between current sense terminals has two functions. First is to delay current sense response during transistor turn-on. There is an inherent delay (1-2 $\mu$s) between “ON” command for transistor and on-voltage fall on transistor. Another function of $C_x$ is to filter current sense signal from spikes generated on current sense resistors.

In overcurrent protection scheme (Fig. 3) transistor current is sensed on non-inductive resistor $R_i$, of appropriate value and dissipation level. This is the only
4. EXPLOITATION EXPERIENCES

Testing and measurements are executed on H-bridge power converter laboratory model dedicated for education purposes. The basic components used are smart driver boards DDM-1 (ENERPRO) based around IC driver chipset LXBD4410/4411 (IXYS) and IGBT power modules ID22212A2 (POWEREX). Load was inductive.

The first expression is that driver boards are very easy to handle and implement on power switch. User has to choose only gate resistors \( R_G \) that are defining turn-on and -off speed of IGBT. During testing very high rise times of IGBT emitter current were achieved (up to 200A/\( \mu \)s) causing intensive voltage spikes because of high \( \text{d}i/\text{d}t \). As such a high switching speed is not necessary, a \( R_G \) value of 42 \( \Omega \) was chosen.

Fig. 6 shows typical results of IGBT's turn-on.

\[ L_{\text{on}} (5 \text{A/div}) \]

\[ L_{\text{off}} (10 \text{A/div}) \]

\[ U_{\text{on}} (10 \text{V/div}) \]

\[ U_{\text{off}} (20 \text{V/div}) \]

During testing, control logic was forced to give simultaneous "ON" signals for lower and upper transistor, but driver board efficiently solved the problem disabling crossconduction of both transistors in a half-bridge leg.

\[ \text{INL (5 V/div)} \]

\[ I_C (2 \text{A/div}) \]

\[ L_{\text{on}} (5 \text{A/div}) \]

\[ L_{\text{off}} (5 \text{A/div}) \]

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The most interesting was testing of overcurrent/desaturation protection circuit, because it is of great importance for educational laboratory to have safe and reliable power switches. Fig. 6 shows results of overcurrent protection. IGBT current was sensed with relatively non-inductive resistor and measured with current probe. It can be seen that control signal INL lasts longer than current pulse $I_C$, because of overcurrent detection and protection work-out at the value of $I_C = 6.5$ A.

Fig. 7 shows results of desaturation (short-circuit) protection. Voltage divider $R1-R2$ was set on relatively lower values of short circuit current. It was not a real short-circuit detection, because current was limited with nonlinear inductor, so the current rise rate was not so fast as in the short-circuit case.

Driver board was working perfectly on frequencies higher than 100 Hz. But when the frequency was lower than 100 Hz, a fault signal occurred. The cause for the problem was in bootstrap circuit for upper part of driver. The capacitor (10 μF) in bootstrap circuit was too small to provide enough charge to maintain $V_{CC}$ voltage for upper part and undervoltage protection worked out. After using greater capacitor (20 μF) the problem is corrected and driver board worked down to frequency of 20 Hz.

5. CONCLUSION

Smart IGBT driver board is a very good solution for power electronics engineers, which simplifies the power converters design tasks. It is flexible in selecting power switch switching speed and the protection scheme. Such a driver board can be applied in power converters using IGBTs or MOSFETs for single- or multi-phase motor control systems, switching mode power supplies, single or 3-phase UPS systems, induction heating and welding etc.

6. REFERENCES