Coreless Transformer Provides Innovative Features

The expansion of the EiceDRIVER-family

Coreless transformer technology was introduced in the market by Infineon Technologies in 2003 [1, 2] as a core technology for IGBT gate drive ICs. Coreless transformer technology may be either used to replace half-bridge drivers, which use level shifters, or to replace optocouplers.

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Since coreless transformer technology provides a total galvanic isolation, negative transients at the high-side floating supply return are not a concern any more. The technology has been improved this year to make it even more resistant to system-level burst stress. Two new parts incorporating new innovative functions for cutting down system cost have been released.

Basics of coreless transformer technology

Coreless transformer technology uses semiconductor manufacturing processes to integrate a transformer consisting of metal spirals and silicon oxide insulation (Figure 1). The transformer is placed on the receiver chip in this example, but it may also be located on the transmitting chip without a change in functionality. Bond wires connect the upper winding with IC 1.

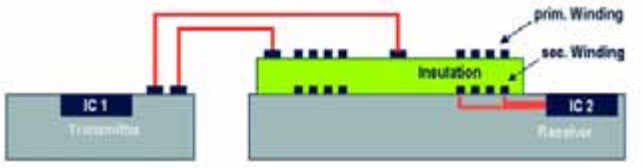

Figure 1: Cross-section of a coreless transformer

It is important to note that this technology is able to transmit pulse information at a rate of several MHz. This is a very big advantage, because it is useful for a wide variety of applications.

Advantages of coreless transformer in comparison to level-shift technologies

Level-shift technologies do not provide galvanic isolation. Therefore, it is impossible to enable features such as reinforced isolation directly with these technologies. Further current paths via the substrate material may lead to malfunction of the IC at specific operating points, if the semiconductor technology does not prevent this by using dielectric isolation or by separating the circuit onto two chips. A critical point is, for example, when the high-side reference potential runs below the potential of the low-side output reference. Then, the high-side output becomes insensitive to control signals. This means that short circuits can be actively triggered repetitively. Excessive power dissipation and system breakdown may result. These kinds of malfunctions can be avoided by using a coreless transformer due to their galvanic isolation.

Since level-shift topologies use high-voltage transistors in pulsed operation to transmit the signal to the high side, there is considerable power dissipation during transmission. This power dissipation is proportional to switching frequency and DC-link voltage. Therefore the applicability in systems with higher switching frequency is limited. Coreless transformer technology does not have this sort of power dissipation. The transmission of the control signal takes place with very low power dissipation in the transmission section. This allows coreless transformer technology to be used in high-frequency switching applications.

Improvements regarding EMI and package: 2ED020I12-FI

The 2ED020I12-FI is a half-bridge driver IC that is fully operational up to 1200 V. Its driving capability is 1 A sourcing and -2 A sinking, which makes this device suitable for IGBT with a current rating of up to 100 A without an additional booster circuit. Figure 2 shows the block diagram of this IC.

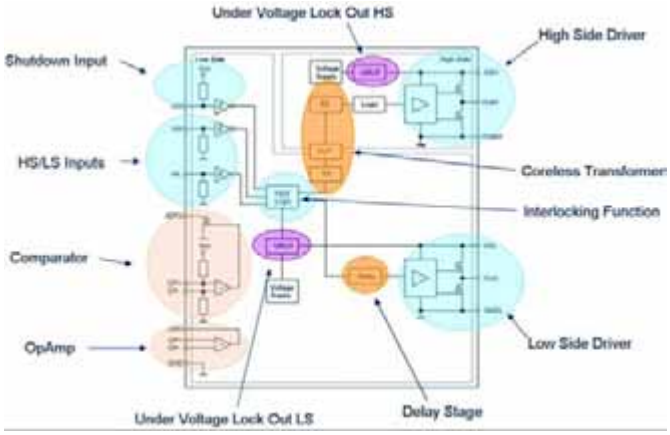

Figure 2: Internal block diagram of 2ED020I12-FI

The non-inverting control input pins for the high-side and the low-side IGBT are compatible with 3.3 V and 5 V TTL logic levels, and contain internal pull-down resistors. The integrated pull-down resistors reduce the number of external components. A dedicated shut-down function at pin /SD can inhibit the transmission of control signals to the high- and low-side drivers. This makes it possible to design a fast shutdown capability in case of a malfunction such as a short circuit.

The propagation delay times with respect of the high-side gate drive signals are very small due to the high frequency transmission of the coreless transformer. However, an additional delay circuit is designed for the low-side gate drive section in order to compensate for the delay time of the coreless transformer of the high side. The delay circuit assures a maximum difference of 10 ns between the propagation delay times.

With an improved transmission protocol compared to the 2ED020I12-F, inverters that use the new 2ED020I12-FI are now able to manage high positive as well as high negative voltages in respect to bus bar ground. Power inverters including the 2ED020I12-FI pass the system-level burst test requirements according to level 4 of IEC 61000-4-4.

An advanced package now allows the 2ED020I12-FI to meet RoHS specifications and mass- production requirements for lead-free soldering.

A unique feature of the 2ED020I12-FI is the integrated comparator and operational amplifier (OpAmp), which can be used, for example, for current sensing by using a shunt according to [3]. Furthermore, the OpAmp and comparator can be used for general functions such as monitoring of the DC link voltage or triggering the start of the chopper, etc.

1ED020I12-S single-channel driver IC with innovative features

The 1ED020I12-S is an advanced, galvanically-isolated IGBT gate driver IC, which was designed to provide reinforced isolation. However, the process to define standards for the reinforced isolation of inductive couplers has just started. A preliminary standard from "Verband der Elektrotechnik Elektronik Informationstechnik e.V." (VDE) for reinforced isolation for magnetic and capacitive couplers is scheduled for publication in December 2006.

Due to the use of a state-of-the-art BICMOS process, control and protection functions superior to those in optocoupler-based drivers could be included. This allows the designer to build highly-reliable designs with fewer components. These functions and features are:

Active Miller clamp
Two-level turn-off
Rail-to-rail output
Desaturation protection with high precision
High-side status signalling with FAULT and READY

The effective active Miller clamp function avoids the need for negative gate driving in most applications. The lack of negative gate bias voltages lowers the system cost effectively, but it is important to avoid parasitic turn-on of the IGBT. High dv_{CE}/dt rates lead to a displacement current through the reverse capacitance ("Miller capacitance") C_{res} and the input capacitance C_{ies} according to the red path in Figure 3. This raises the gate voltage according to the transfer characteristic of the capacitive voltage divider. If the voltage shift is higher than the Miller voltage of the IGBT, parasitic turn-on of the IGBT is caused. This leads to a short-term short circuit of the half-bridge, and increases switching losses significantly. The gate resistor Rg actually decouples the gate-drive stage of the IC from this effect [4]. The active Miller clamp (pin CLAMP) now connects directly the gate pin of the IGBT module with an integrated, low-ohmic FET and pulls it down effectively, so that the IGBT is kept off. The integrated FET is able to sink up to 1 A.

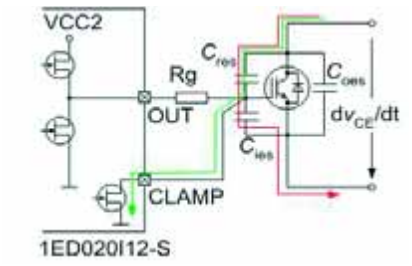

Figure 3: Application circuit using the active Miller clamp function of 1ED020I12-S

The two-level turn-off optimizes the switching of the IGBT in case of short circuits or severe overcurrents. By activating two-level turn-off, the gate voltage prior to turn-off is reduced to a programmable level in order to reduce the carrier density in the IGBT. This action avoids a dangerous excessive overvoltage across the IGBT during short-circuit turn-off. The intermediate level of reduced gate voltage is defined by the voltage of the external Zener diode D_{TL} as shown by a) in Figure 4. The turn-off delay T_{TL} shown in b) of Figure 4 is programmable through an external capacitor C_{TL} for accurate timing. The turn-off delay T_{TL} is also used to delay the turn-on signal to prevent distortion of the input-pulse width. The overvoltage with two-level turn-off activated is significantly lower compared to short-circuit turn-off without this protective feature. This considerably increases the reverse bias safe operating area (SOA) of the IGBT and the module, respectively. Although two-level turn-off is also in operation for normal switching events, it does not have an adverse effect on switching losses.

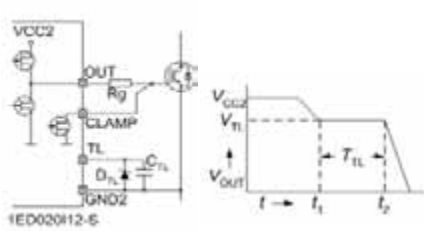

Figure 4 Two-level turn-off
a) Application schematic
b) Timing

Another new feature is the rail-to-rail output. This means, that the gate-drive voltage reaches the supply voltage V_{CC2} according to Figure 5. A rail-to-rail driver output enables the user to provide easy clamping of the IGBT gate voltage during short circuit of the IGBT via a Schottky diode from the gate pin of the IGBT to the high-side supply of the 1ED020I12-S. Thus, an increase of short-circuit current due to the feedback via the Miller capacitance can be avoided. Common gate-drive ICs do not offer this feature. Therefore, the supply voltage of the output stage is increased to 17 V or 18 V in order to obtain a gate-emitter voltage of V_{GE} = 15V. As a result, effective gate clamping with a diode to the supply is not possible with common gate-drive ICs that do not provide a rail-to-rail output.

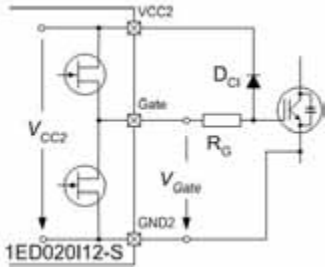

Figure 5: Rail-to-rail output and effective gate-voltage clamping

These features are important steps toward building very reliable, high-performance, high-power drive systems. They reduce the component count dramatically by comparison with standard approaches using optocouplers. Figure 6 shows two gate-drive PCBs for half-bridge modules, each with the same functionality.

The upper photo shows the evaluation board of 1ED020I12-S for a half-bridge driver design, which supports all functions of the 1ED020I12-S. This design saves four optocoupler and a large number of discrete components that would be necessary to provide the same features. The evaluation board is available from December 2006 onward.

Conclusions

The coreless transformer technology is very attractive for gate-drive ICs. Infineon's existing portfolio with the 2ED020I12-F has been expanded by adding the new half-bridge driver 2ED020I12-FI and the single-channel driver 1ED020I12-S. Coreless transformer technology is very robust and can easily be combined with innovative functions such as active Miller clamping, two-level turn-off or rail-to-rail outputs. These functions help design engineers to meet their targets in terms of cost, reliability, and time-to-market.

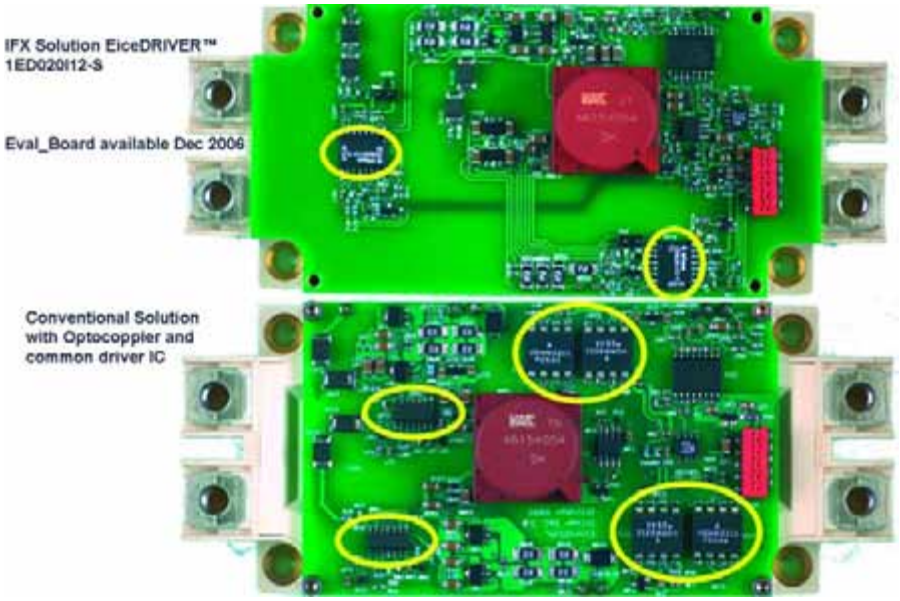

Figure 6: Fewer components in a PCB designed with 1ED020I12-S (upper design)

References

[1] B. Strzalkowski: "A monolithic integrated transformer in control circuitry of power electronics"; EDPE 2001 Kosice/Slovak Republic
[2] M. Münzer, et al.: "Coreless Transformer a new technology to drive power semiconductors the intelligent way"; Proceedings of PCIM 2003; Nürnberg, 2003
[3] A. Volke, et al.: "IGBT/MOSFET Applications based on Coreless Transformer Driver IC 2ED020I12-F"; Proceedings of PCIM 2004, Nürnberg, 2004.
[4] Infineon Technologies: "Driving IGBTs with unipolar gate voltage"; Application Note AN-2006-01, Infineon Technologies, Germany, 2005.

www.infineon.com/gatedriver