

Insulated signal transfer in a half bridge driver IC based on coreless transformer technology

M. Münzer¹; W. Ademmer¹; B. Strzalkowski²; K. T. Kaschani²
¹eupec GmbH, ²Infiniteon Technologies

Abstract - Signal transmission across an insulation is a technical challenge in many applications. State of the art solutions use either optical devices (opto-couplers; fibre optics) or magnetic pulse transformers. By integrating two planar coils on a silicon die, an inexpensive coreless transformer has been developed, that incorporates the advantages of a pulse transformer into an IC. This paper gives information on transmission behaviour, insulation capability and potential fields of application of the new technology.

Keywords – Gate driver, coreless transformer, IC

I. REQUIREMENTS FOR INSULATED SIGNAL TRANSFER

Although fields of application for insulated signal transfer can be found in such different areas as computer interfaces, sensors, control panels or gate drives its requirements can be reduced to a few major points. First of all insulation has to withstand not only the applied voltage stress over the whole life time but must also comply with the applicable standards. Another important issue on insulated signal transfer is transfer rate and run time. Usually these two requirements are in contradiction to the stability of the signal. A signal which is rugged versus EMI and does not degrade over time however is a necessity with high priority. Further requirements are costs, energy consumption and robustness versus external stress e.g. temperature stability. Importance of points mentioned above may vary by application but all of them have to be fulfilled.

II. COMPARISON OF COMMON TECHNOLOGIES

For insulated signal transfer optical devices (opto-couplers; fibre optics) and magnetic pulse transformers are common. High voltage IC's with level shifters circuits are also often used to transfer a signal to an independent potential. But as this technology only provides a quasi insulation high voltage IC's with level shifters fall into a different category. In terms of insulation capability fibre optics and pulse transformer based on ferrite cores provide excellent values. However both solutions are quite expensive. For integration in an IC optical solutions are common. These opto-couplers can be manufactured at reasonable costs, but they degrade over time. Due to the low transmission rate of opto-

devices implementation of a magnetic pulse transformer in an IC is interesting. A list of pros and cons of the various technologies is shown in figure 1.

Comparison of insulated signal transfer concepts

Feature	Opto Coupler	Fibre Optics	Pulse Transformer
Insulation Capability	0	++	+
Transfer Rate	0	0	+
Run Time	+	0	+
EMI Stability	+	++	+
Reliability	-	0	+
Thermo Stability	-	0	+
Mechanical Robustness	0	-	+
Energy Consumption	0	0	-
Logic Integration	++	-	-
Energy Transfer	--	--	+
Size	+	0	--
Costs	+	0	-

Fig. 1. Comparison of off-the-shelf insulated signal transfer technologies.

III. CORELESS TRANSFORMER TECHNOLOGY

Main idea of the coreless transformer technology is to combine the advantages of a pulse transformer with the advantages of IC production technologies. For realisation the logic functions of the transmitter are build into a primary die. The secondary die holds the receiver as well as primary and secondary windings of the transformer. Both dies are soldered to a split lead frame. Connection between transmitter and primary side of the transformer is made by wire-bonding. Afterwards the chip set is covered in molding compound (figure2).

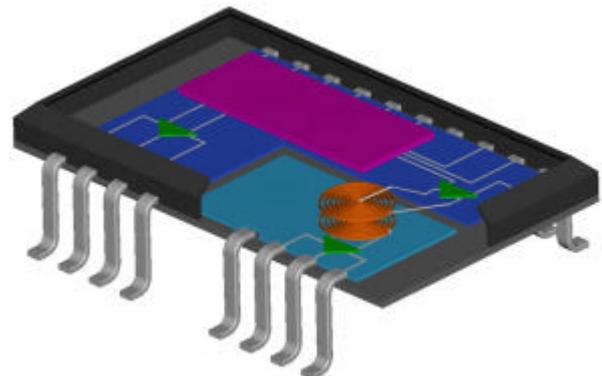


Fig. 2. Sketch of coreless transformer technology.

For the logic functions SPT5 a well established smart power BiCMOS technology designed by Infineon Technologies for automotive applications is used. Although transmitter and receiver have to be adjusted to the characteristic of the planar transformer IC technology for these components is well established. Layout and production processes for the transformer are the real challenges in the development of a coreless transformer IC. In traditional pulse transformers the magnetic flux is directed by the core (figure 3). For integration in an IC a magnetic core is not suited due to size as well as process ability. The solution for getting a good coupling factor between primary and secondary windings despite the absence of a core is in the design of planar coils. Here both windings have a spiral form, as can be seen in figure 2. Planarity makes it possible to place the windings close to each other. As strength of magnetic field around a lead declines by $(1/r)^2$, reducing the distance between coils is vital for the functionality (figure3).

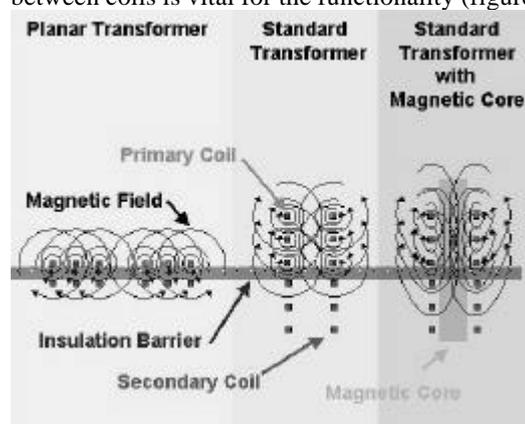


Fig. 3: Magnetic coupling of various coil designs

Limiting factor for the reduction of distance is the necessary thickness of the insulation material. Quality of insulation however is not only determined by distance. Choice of material and its homogeneity as well as electric field distribution between the two coils influence the electrical stability. Due to the physical design of the transformer and the process technology at Infineon it is possible to reduce the distance between windings of the coreless transformer up to a few micrometer. First IC's in the new technology have been produced and tested.

IV. TEST RESULTS INSULATION CAPABILITY

To test the capability of coreless transformer technology a half bridge driver IC for IGBT and MOS-FET applications was chosen. This device named 2ED020I12-F consists of a low side driver chip with additional logic functions and a high side driver chip. The two chips communicate via the coreless transformer on the high side chip. Aim was to design the transformer thus that it would withstand DC-voltages of 6kV which is the

required insulation voltage for safe isolation in applications with working voltages up to 890V according to EN50178. The first production lot of prototypes had a yield in the 6kV insulation test of 100%. A destructive insulation test on a limited amount of samples showed a very narrow distribution (figure 4).

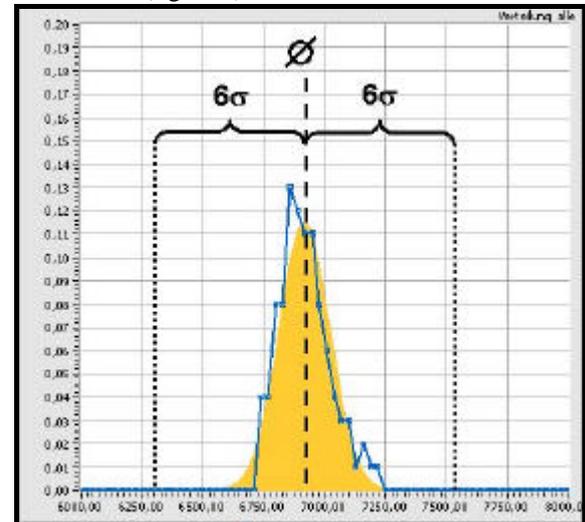


Fig. 4: Distribution of insulation voltage

While the standards only require initial tests for DC stability and partial discharge, additionally AC - and long term stability have been tested successfully with the first samples of 2ED020I12-F.

V. TEST RESULTS TRANSFER CHARACTERISTIC

The transfer characteristic of the coreless transformer is determined not only by the physical layout of the transformer but also by the transfer algorithm. Signal transfer from primary coil to secondary coil is almost instantaneously (figure 5).

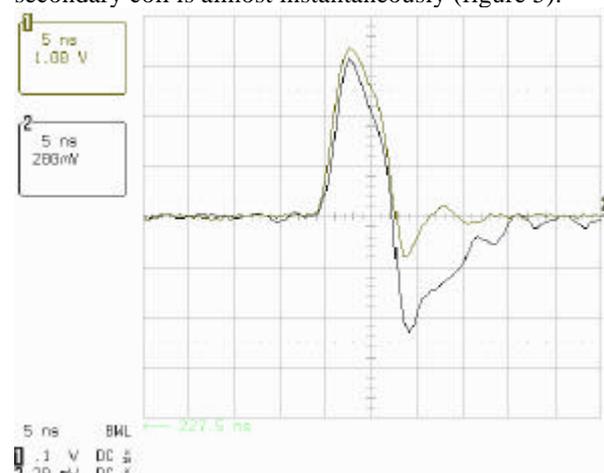


Fig. 5: Signal transfer primary to secondary coil

Coding and decoding of the signals however add up to a run time of still less than hundred nanoseconds. Coding and Decoding is necessary for various reasons. First of all the input and output signals are steady state signals, but the transformer can only transmit pulses. Using a transformer design that is

suiting for common mode rejection time is also needed for filtering as well as generation of corrective signals if needed. For the user of a coreless transformer only the transfer characteristic at the pins is of interest. Measurements of the Run time of the test device 2ED020I12-F show values of less than 50ns between input and output signal (figure6).

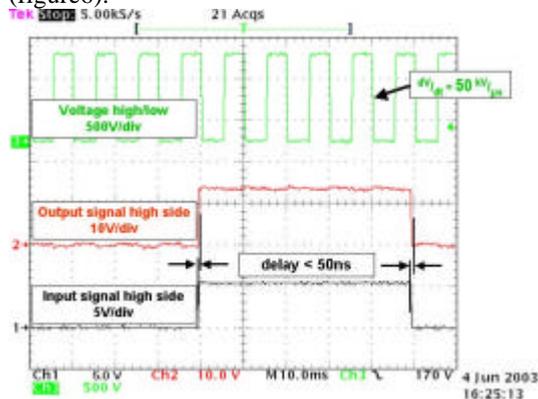


Fig. 6: Signal transfer input to output 2ED020I12-F

In figure 6 the high dV/dt immunity of the coreless transformer can also be seen. The black trace shows the input signal for the high side driver. The red trace shows the output signal. These two signals are both stable and uniform although the output stage of the driver is shifted between 0 potential and 1000V with a slope of more than $50kV/\mu s$ as can be seen from the green trace. A necessity for good EMI behaviour is low coupling capacity. For the transformer itself the coupling capacity is in the magnitude of 200 Femto farad. Due to the lead frame of the IC however the external value will rise to approximately 1 Pico farad. As the coreless transformer is a magnetic coupling device, its sensitivity versus electro magnetic fields seems to be limited. Test results however show a different picture. Putting a coreless transformer into an air core inductor (figure 7) it can be exposed to magnetic field changes of $100^{A}/(m*ns)$ in all axis without causing EMI problems.



Fig. 7: Test set up for magnetic noise

The coreless transformer has also been tested for high frequency electro magnetic fields. Under such conditions the design of the planar transformer on top of the lead frame helps to prevent malfunction.

The lead frame will work as a shield, as eddy currents induced into it will deflect external magnetic fields (figure 8).

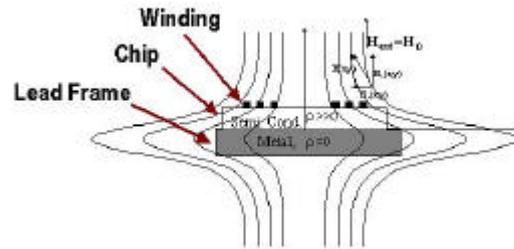


Fig. 8: Deflection of external magnetic fields

The superior transfer characteristic of the coreless transformer makes it an ideal technology not only for driver IC's but also for all other applications where an insulated signal transfer is necessary.

VI. DRIVER IC'S BASED ON CORELESS TRANSFORMER TECHNOLOGY

First application of coreless transformer technology is a half bridge driver IC for MOS-gate controlled devices. The product is called 2ED020I12-F and is part of the new *EiceDRIVER™* family at eupec GmbH. A functional block diagram can be seen in figure 9.

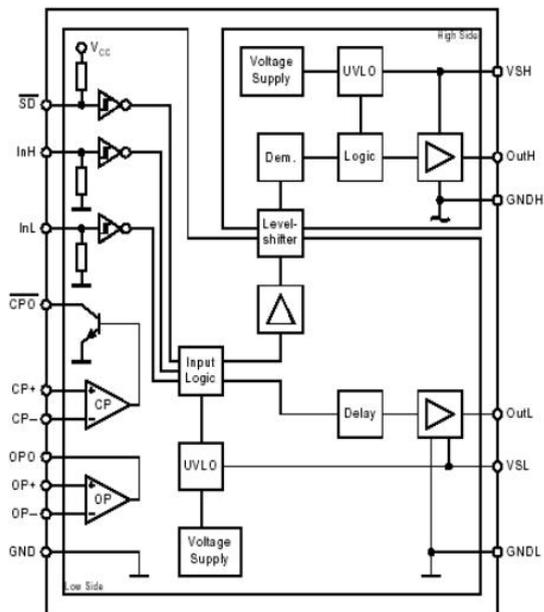


Fig. 9: Block diagram 2ED020I12-F

As the low side driver of this device is on the same potential as the input stage a safe insulation of the high side is not reasonable. Being based on SPT5 a silicon technology that supports logic functions an integration of additional logic components that fit into the chosen housing seems advisable. In case of the 2ED020I12-F an operational amplifier and a comparator on the low side have been added. During the design of the operational amplifier focus was out on its speed. With a gain band width of

close to 70MHz and a slew rate of up to 50V/μs it is suitable for fast current measurement. In figure 10 a circuit diagram for a current measurement in the DC – link as well as a current measurement via an emitter shunt can be seen.

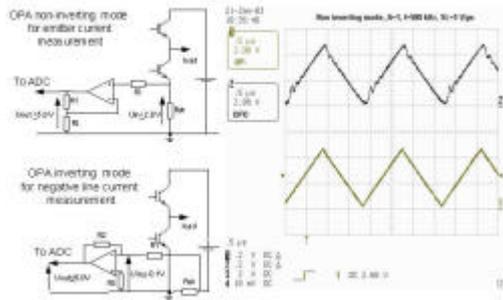


Fig. 10: Circuitry for current measurement with operational amplifier & transfer characteristic of operational amplifier

Figure 10 also shows the transfer characteristic of the operational amplifier in non inverting mode. Even at an amplification of 1 the operational amplifier is stable under the shown conditions.

VII. CONCLUSION AND FUTURE DEVELOPMENT

In this paper a new insulated signal transfer technology called coreless transformer was introduced. The pros and cons can be summarised as seen in figure 11.

Pros and Cons of Coreless Transformer Technology

Feature	Cost	Insulation	Transformer size	Turn time	EMI/EMC	Reliability	Flexibility	Thermal resistance	Manufacturing	Efficiency	Energy storage	ESD	Core
Coreless Transformer	○	●●	●●	●	●	●	●	●	●	●	●●	-	●●

Fig. 11: Pros and cons of coreless transformer technology

Apart from introduction of the new technology test results of a prototype as well as the features of a first product that is based on the coreless transformer technology have been shown. Due to its excellent performance, the coreless transformer will be used in a variety of future products made by Infineon and eupec. Following the introduction of the 2ED020I12-F a driver IC which will feature safe insulation

References

- (1) K. Krieger, Dissertation, "Integriertes Energie- und Datenübertragungssystem, Modelbildung und systemorientierte Optimierung von monolithisch integrierten Mikrospulen, Fachbereich Physik und Elektrotechnik, Universität Bremen, April 1999
- (2) Y.Hui, H.Shu-Hung Chung, S.C.Tang.: Coreless PCB Transformers for Power MOSFET/IGBT Gate Drive Circuits, IEEE Transaction on Power Electronics, V.14, No.3, May 99
- (3) B. Strzalkowski: A monolithic transformer in control circuitry of power electronics, EDPE 2001 Kosice/Slovak Republic
- (4) A. Niknejad, R. Meyer.: Analysis, Design, and Optimization of Spiral Inductors and Transformers for SI RF IC's, IEEE Journal of Solid State Circuits, Vol. 33, pp. 1470-1481, Oct. 98
- (5) K. Kaschani, B. Strzalkowski, M. Münzer, W. Ademmer: Coreless Transformer a new technology for driver Ics, PCIM 2003, Nürnberg