

Coreless transformer a new technology for half bridge driver IC's

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To drive the high side switch in a half bridge configuration it is necessary to transmit signals from the micro controller to the floating high side potential. Depending on the performance level of the drive circuit either HV IC's with different kinds of level shifters, opto-couplers or transformers are employed for signal interchange. HV IC's with level shifters are comparably inexpensive, but they can not on principle grant galvanic isolation. Opto-couplers on the other hand do provide safe isolation, but they degrade over time. Especially in high performance drives discrete transformers are the common solution, although they are rather expensive. By integrating both windings of a coreless transformer on a silicon die, Infineon Technologies in cooperation with eupec developed a costeffective solution, that incorporates the advantages of a transformer into an IC. This paper describes the technology used to build a first half bridge driver IC. First measurements on signal transmission as well as insulation voltage are shown. Being capable of integrating various functions into the IC, potential features for a half bridge driver are discussed.

Gate drives- demands and market

MOS controlled power semiconductors are state of the art in the industry. To drive these devices in a drives application it is necessary to apply a voltage across emitter and gate that refers to the PWM signal of the micro controller. As the output signal of the micro controller is not powerful enough and has a low voltage rating it needs to be amplified and the voltage level adjusted. If the power device is on the same potential these functions for a gate driver would be sufficient, but in most cases the potentials of emitter and micro controller differ.

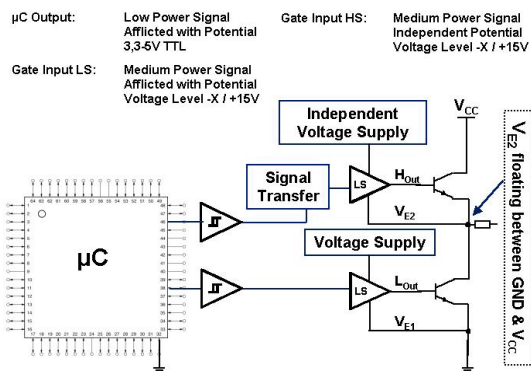


Figure 1: block diagram half bridge configuration

Looking at a half bridge configuration (Figure 1) as it is common in power electronic circuits it is easy to see that the voltage between micro controller and high side emitter V_{E2} is not only

different, but varies during operation. To transmit the PWM signal from the micro controller to the power semiconductor on the high side a signal transmitter of some kind is necessary. Summarizing one can say that the minimal functionality of a gate drive is amplifying and level shifting.

Concepts for level shifting

Industry standards demand a safe (galvanic) isolation between power stage and control panel of a frequency converter. In most low performance drive applications it has been more cost efficient to implement this isolation between panel and micro controller.

Level Shifter Circuit

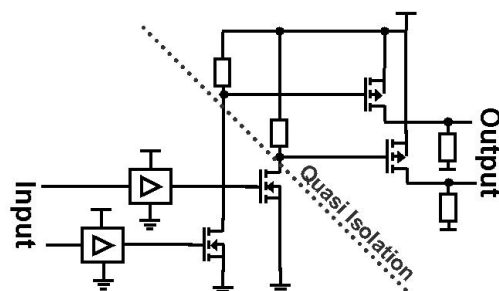


Figure 2: Circuitry of a monolithically integrated level shifter with quasi isolation

As no further insulation between micro controller and power stage is needed, high voltage IC's with monolithically integrated level shifter circuits like the one shown in figure 2 can then be used. These IC's are very cost efficient for voltages 600V and below. For higher voltages the silicon area needed for the quasi isolated barrier between input and output makes this solution expensive. Drives with a higher performance level usually demand for an isolation between micro controller and power stage. First choice for these drives have been opto couplers which are available with a safe isolation for applications with a working voltage of up to 890V. A major drawback of all opto coupler solutions is the transfer characteristic which is rather slow and even worse changes with time. Fibre optics have the same problem, except for not being limited to 890V applications. High isolation voltages can also be achieved with pulse transformer designs. The transfer characteristic of these discrete pulse transformers is favourable, but costs and physical size are reason enough to search for new solutions. The coreless transformer a monolithically integrated planar devices is one of these new solutions.

Coreless Transformer Technology

The main idea of the coreless transformer technology is to integrate the two coils of a transformer into an IC as can be seen in figure 3. While a discrete transformer needs a core to direct the magnetic flux the coils in an IC can be placed close enough to save the core.

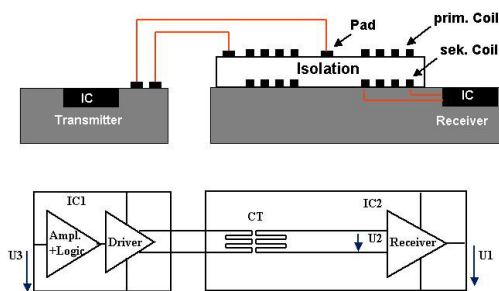


Figure 3: Coreless transformer principle

Due to the design and size of the coils the coupling capacity can be reduced up to such a low level, that the total capacity between input and output is dominated by the lead-frame design of the housing. An intelligent coil design also makes it insensitive to external magnetic fields. To guarantee safe isolation for

applications with a working voltage of up to 890V the barrier between the coils needs to withstand a voltage of 6kV according to EN50178. Figure 4 shows results of a partial discharge test performed at coreless transformer devices with an insulation made of silicon oxide which had seen extended stress tests.

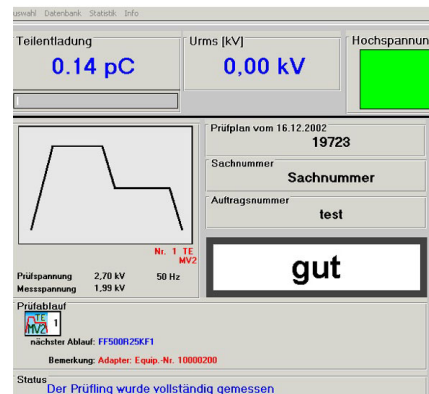


Figure 4: Results of partial discharge tests

Silicon oxide is a common technology for isolation in an IC, but only with an adequate production technology these can be grown up to a sufficient thickness. With Infineon's SPT5 a BCD IC-technology mainly developed for automotive applications is available that supports the processes to realise planar high isolating transformer. As the transformer is only capable to transmitting narrow pulses, a dedicated transmitter and corresponding receiver are integrated. While the receiver is placed on the same chip as the transformer, the transmitter is located on a separated chip. Bond wires connect this transmitter to the primary coil of the transformer. A photo of a prototype which shows the transmitter, bond connection, coils and receiver can be seen in figure 5.

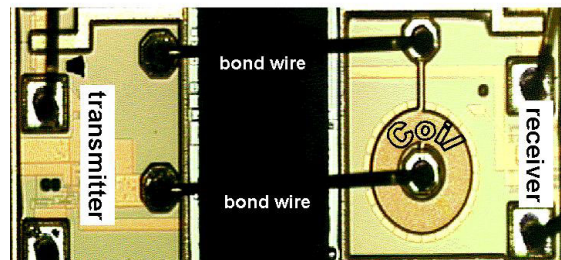


Figure 5: Photo of a coreless transformer chip set

Signal Transfer

The pulse response of a planar transformer is typically less than 2ns. Furthermore it shows almost no degradation over time or temperature. Consequently, a planar transformer requires a transmitter and receiver, which are both capable of fast signal processing. External noise can be suppressed almost completely by an appropriate transformer design. Furthermore, for application in extremely noisy environments intelligent signal transmission and filtering is provided. In this way transients of the external magnetic flux and of the high side reference voltage up to 50kV/μs can be handled. While the propagation delay of the planar transformer and its transmitter and receiver is about 20ns, the overall propagation delay of the developed IGBT driver is about 50ns (figure 6). Voltages in figure 6 are named according to designations in figure 3.

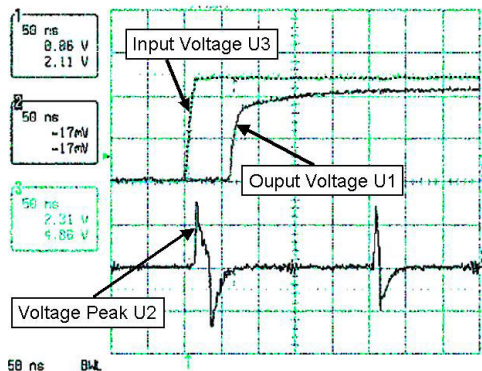


Figure 6: First measurements of a coreless transformer prototype

Due to the high transfer rate of up to 100 MHz the coreless transformer technology is not only suited for gate drive units. It can be used as base technology for all kinds of products which demand (safe) insulation and a high data rate.

2ED02012-F – First IGBT gate drive based on a coreless transformer

Over the last year eupec GmbH has created a new family of IGBT gate drives called EICE-Driver. For medium power applications the 2ED02012-F is now available. A block diagram of the driver is shown in figure 7.

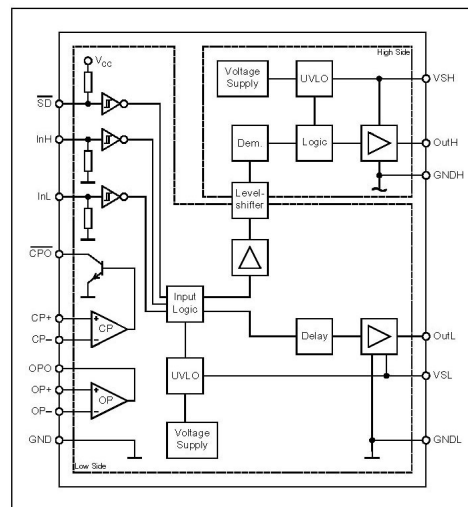


Figure 7: Block Diagram 2ED02012-F

2ED02012-F is a half bridge driver with functional isolation for the high side driver stage and an output rating of 2A. Low side driver stage and input are integrated on the same chip along with an additional general purpose operational amplifier. Standard logic functions like under voltage lock out for high and low side are also on board. To meet the necessary creepage distances for functional isolation P-DSO-20 housing with two non existing pins as shown in figure 8 was chosen for the 2ED02012-F.

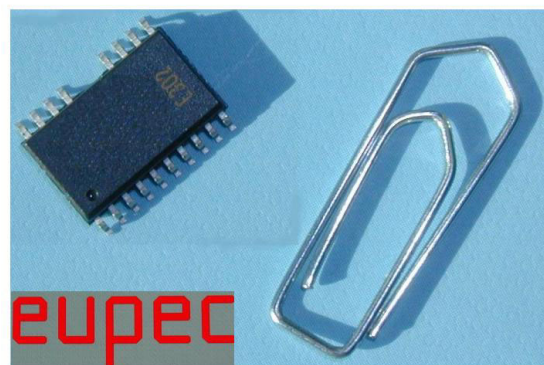


Figure 8: Photo of 2ED02012-F

Conclusion

This paper shows that amplification and level shifting are the main tasks of a gate drive. Various technologies for level shifting have been discussed. With coreless transformer technology a new way to design a signal transmitter with galvanic isolation has been

introduced. Main advantages and disadvantages of the discussed level shifting technologies are summarized in figure 9.

Comparison of level shifting technologies

1.) IC with monolithically integrated level shifter circuit	
+ cheap	- quasi isolation
+ integration of logic functions	- only available for $\leq 1200V$
+ big temperature range	- slow
	- sensitive to EMI
2.) Opto couplers	
+ isolation capability	- expensive
+ EMI stability	- aging transfer characteristic
	- reliability
	- slow
3.) Discrete pulse transformer	
+ isolation capability	- expensive
	- size
	- energy consumption
4.) Coreless transformer	
+ isolation capability	
+ cheap	
+ integration of logic functions	

Besides physical design the measures needed for an efficient signal transmission have been mentioned. At the end a first product that incorporates coreless transformer technology was shown. This product does not fully utilize the isolation capability of the coreless transformer. In a next step eupec GmbH in connection with Infineon Technology will develop a gate drive which features safe insulation. Only then full utilisation of the new concept will be made. Further product ideas have already been evaluated and will follow.

Figure 9: Summary on level shifting

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