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# INSULATED GRID BIPOLAR TRANSISTOR DRIVE INSULATED BY A PIEZOELECTRIC TRANSFORMER

## Abstract

The drive of an insulated grid power transistor (MOSFET or IGBT) requires a strong galvanic insulation in order to limit parasitic couplings and because of reliability reasons. A new gate drive for MOSFET and IGBT has been studied based on the use of a piezoelectric transformer. Recently, because of the needs for miniaturization this kind of transformer has found practical applications,

such as power supplies for portable computers. The characterization of the transformer and the analysis of the energy transfer to the grid of the transistor are achieved in order to determine the optimal physical structure of the transformer. The piezoelectric transformer is supplied at a constant frequency which is its mechanical resonance frequency. The driving signal is

transmitted by pulsed squarewave modulation. This transient functioning of the piezoelectric transformer was not studied until now. The signal is demodulated in the secondary part of the drive by a diode demodulator which drives the transistor grid. Satisfactory results have been obtained in driving a 4A/100V/20kHz chopper.

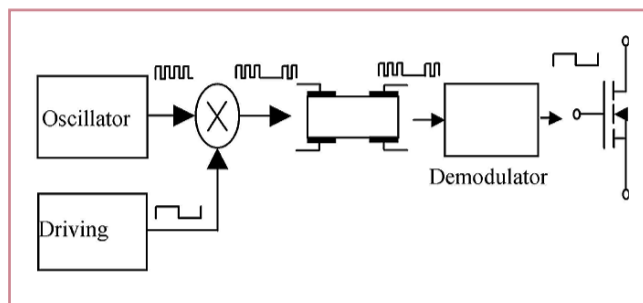


Fig 1: Structure of the command

The piezoelectric transformer is supplied by an alternating voltage at a constant frequency which is its mechanical resonance frequency. The driving signal is transmitted by pulsed squarewave modulation.

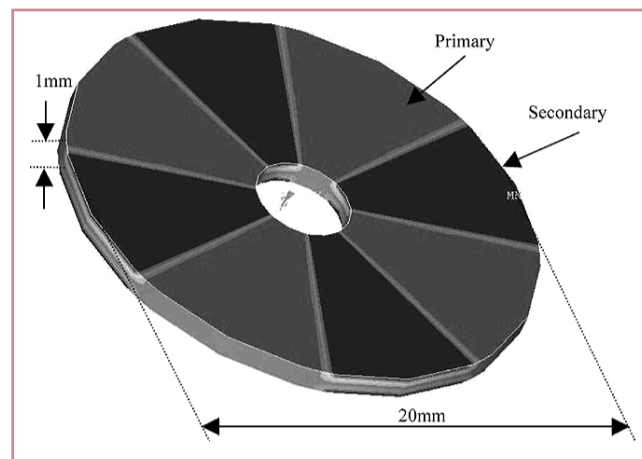


Fig 3a : Prototype piezoelectric transformer

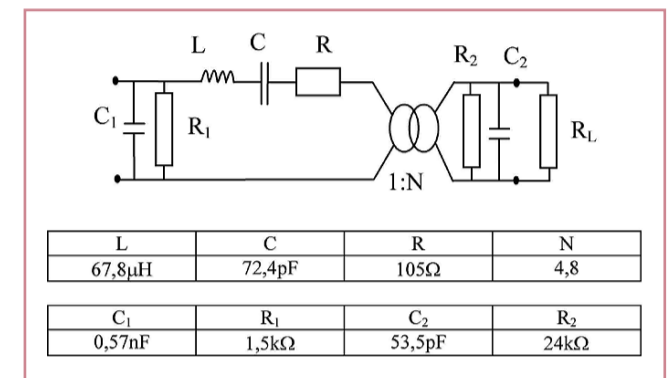


Fig 4: Transformer equivalent circuit

The equivalent circuit is presented in figure 4. The RLC series circuit represents the motional branch, it describes the mechanical oscillations of the material. The model has been calculated in relation to the armature arrangements and to the material properties. Experiments have confirmed theoretical calculations. The output capacitance C2 and input capacitance C1 represent the capacitance of the armatures of the transformer. The transformation ratio is represented by the ideal transformer 1:N.

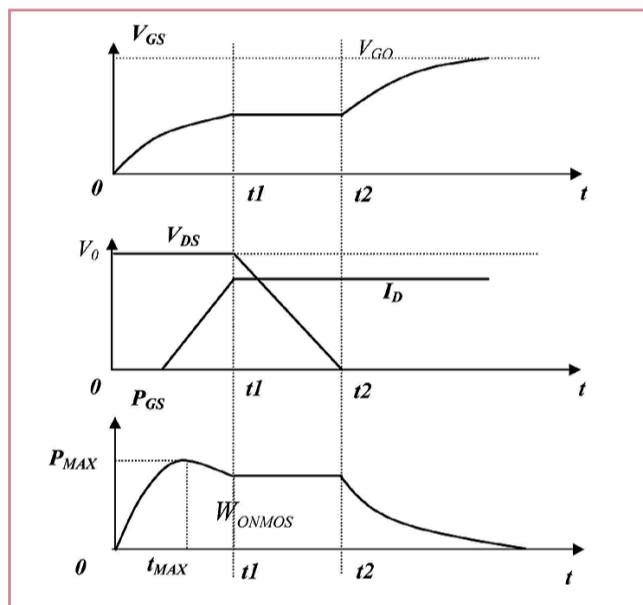


Fig 2: Variation of the input power during the commutation of the switch

The drive must provide the energy to the transistor only during commutations as depicted in figure 2. Note that the energy is brought to the MOSFET grid only during the switching times. The transistor is switching at frequency F. So, the average power of the transformer must be greater than:  $P_{Total} = V_G Q_G F$ . However the maximal power can be very high.

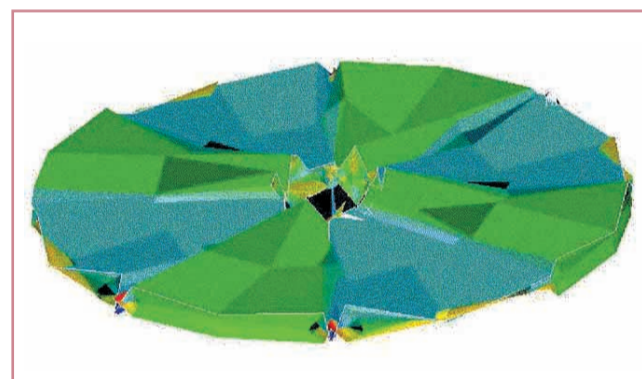


Fig 3b: Calculated deformations of the piezoelectric transformer

The transformer is divided into eight insulated sections (a section is a pair of facing armatures) (fig. 3). Four sections are connected in parallel at the input, four sections are connected in series at the output. The primary and secondary sections are alternated. This arrangement has been chosen in order to increase the transformer gain. The mechanical deformation of transformer is shown in figure 3b.

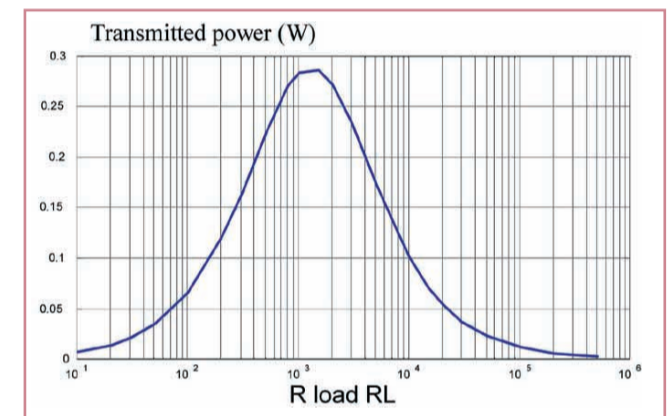


Fig 5: Power transmission versus load resistance of the transformer

A particular attention has been paid to transient behavior, because it determines widely the dynamic performances of the drive. It has been demonstrated that an optimal transient time (or response time) can be obtained if the load is well matched to the transformer parameters (R, N) and to the properties of the transformer material, as it is shown in fig. 5.

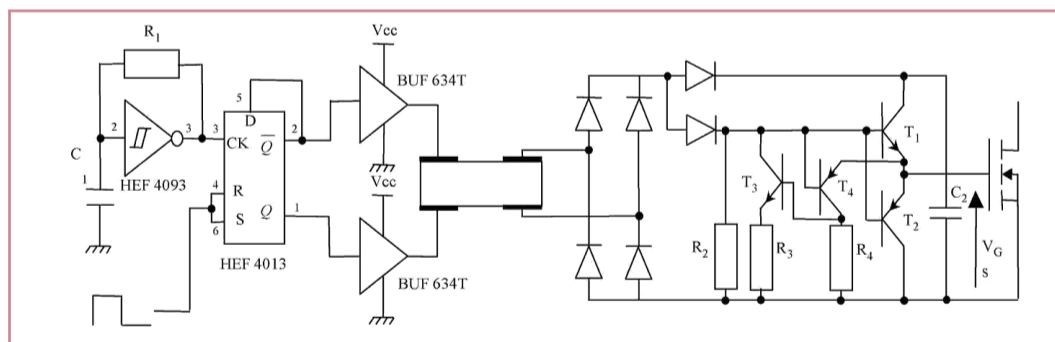


Fig 6a: Electrical circuit of the piezoelectric drive

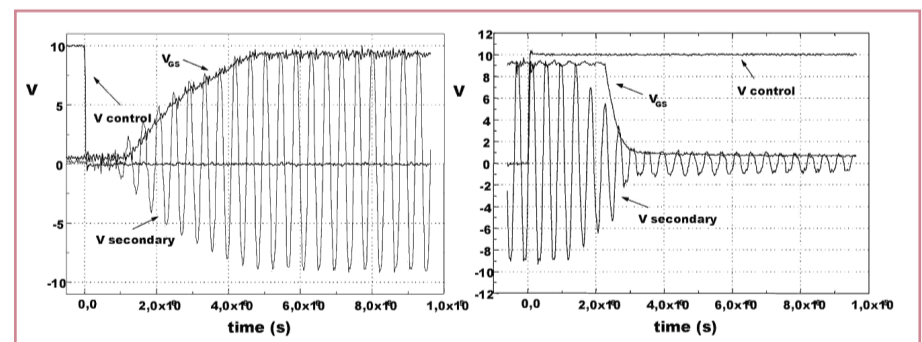


Fig 7: Transient phenomenon

Figure 7 illustrates the transient phenomenon when the pulsed sine wave is applied to the transformer.

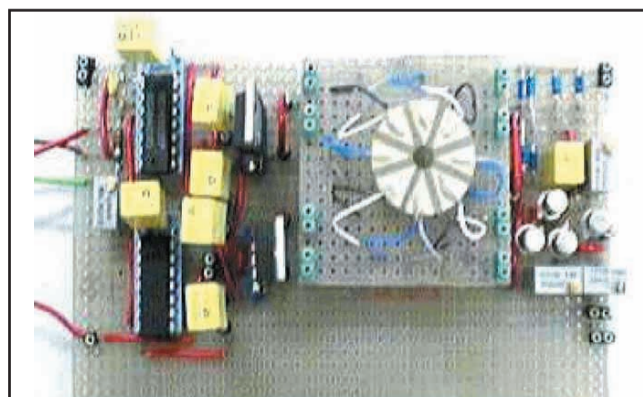


Fig 6b : picture of the drive

The constraints due to the small power transmission capability and due to the dynamic response of the transformer led us to carry out a specific control (fig. 6). The capacity C2 ensures to provide the crest power during switching. It is recharged during the rest of the period.

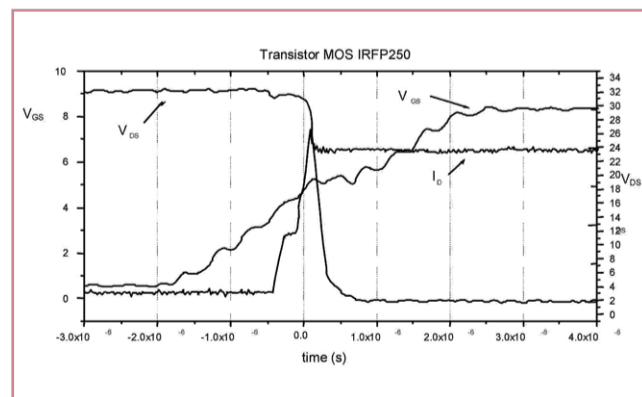


Fig 8: Waveforms in the IGBT at switching-off

Figure 8 shows a zoom of the switching transient of the current  $I_D$ , and of the voltages  $V_{DS}$  and  $V_{GS}$  during the switching-off of the transistor.

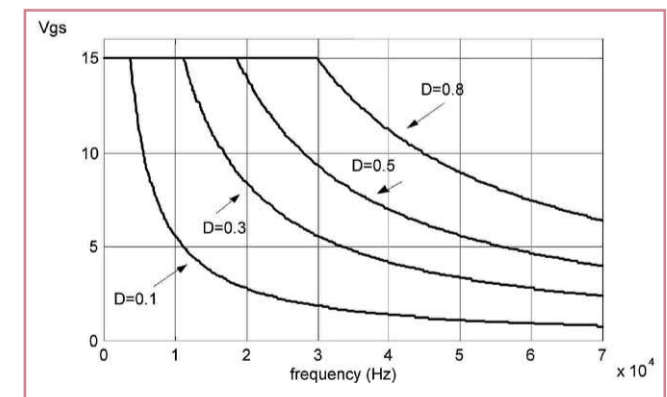


Fig 9: Limits of power transmission

However, the limited power transmission capability associated to the modulation strategy restricts the driving capabilities of this drive. A usable characteristic has been calculated in order to define an available area in the frequency and duty cycle D area, as depicted in figure 9.

## Conclusion & Perspective

The ideal structure of the transformer for such an application is to stack thin films of piezoelectric materials and insulating layers (reduction of the propagation time). This structure induce a good

mechanical coupling between the primary and the secondary (in order to increase the efficiency). The last improvement that we are going to realise is to insert an

electrostatic screen in the insulating layer, connected to the ground, in order to improve the immunity of the drive to the electromagnetic disturbances.