Practical Considerations in designing High-Inductance, High-Voltage IGBT Circuits

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Introduction

Insulated-gate bipolar transistors (IGBTs) are high-power switches with application in

- **Electric vehicles**
- **Multi-phase inverters**
- **Induction ovens**
- **Transcranial Magnetic Stimulation (TMS)**

Our project involves the latter, TMS, which is the science of stimulating the deep brain with high-power electromagnets. Early in the project, we ran into a major problem.

WHY DO OUR IGBTs KEEP DYING?

To determine the reason, we reviewed the papers of our model project, *Peterchev et. al* [1], and eventually implemented three distinct circuit elements: the snubber, the gate driver, and Litz wire. Equivalent implementations of Peterchev's work were developed by economical means.

Methodology

Circuit elements from the circuit depicted in Fig. 1 were removed one at a time to test the individual effectiveness of each on the related para-meter. Because of time and usage constraints, the Litz wire was only partially re-placed by solid doorbell wire. Snubber values were initially determined from Eqn. 1 and 2 [2].

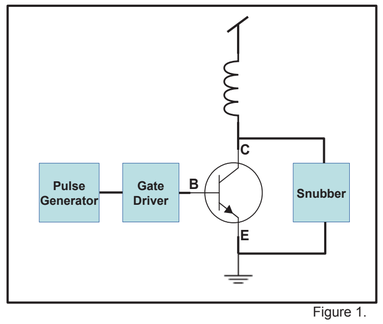


Figure 1.

$$C_{sn} = \frac{L_s I_o^2}{(V_{pk} - V_{cc})^2}$$

Equation 1.

$$R_{sn} = \frac{1}{6 C_{sn} f_{sw}}$$

Equation 2.

Results

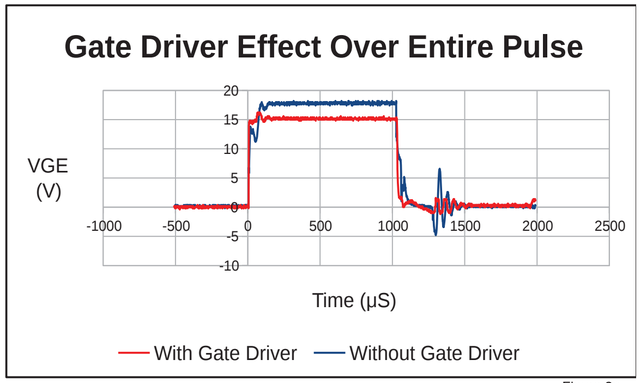
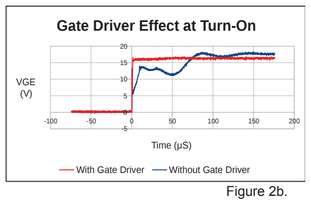


Figure 2a.



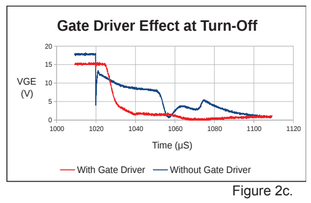


Figure 2b. Figure 2c.

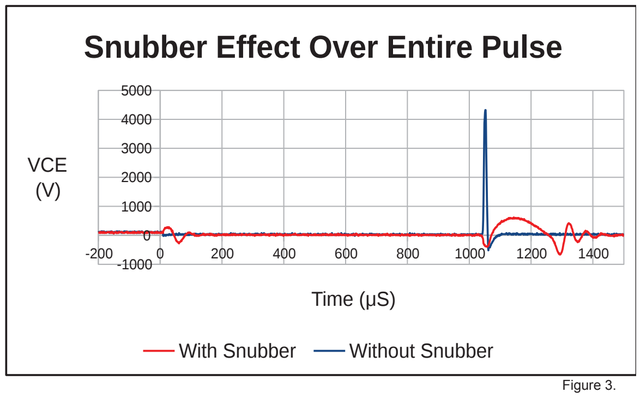


Figure 3.

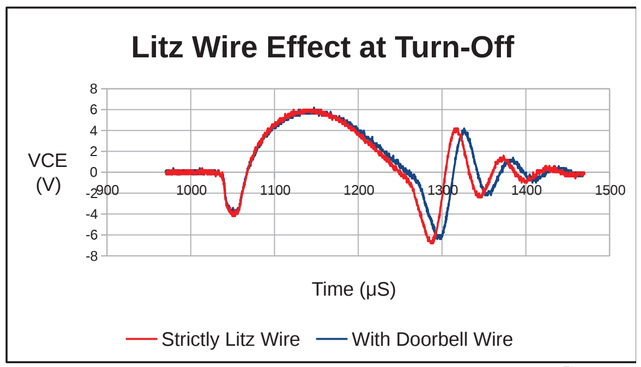


Figure 4.

The Elements

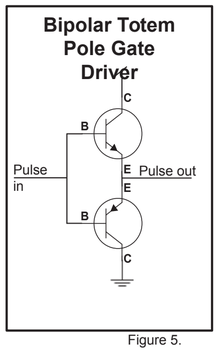


Figure 5.

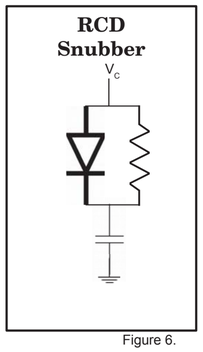


Figure 6.

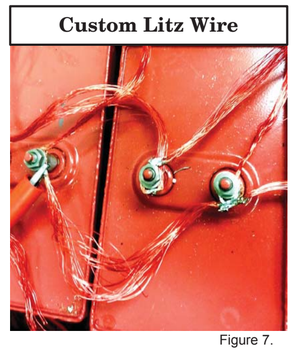


Figure 7.

Conclusions

The following can be inferred from the results column:

- **The gate driver (Fig. 5) effectively reduces both turn-on and turn-off time (Fig. 2).**
- **The snubber (Fig. 6) effectively reduces the kick-back voltage spike over the IGBT (Fig. 3).**
- **The Litz wire (Fig. 7) has a small effect on the oscillation speed of V_{CE} at turn-off (Fig. 4).**

Further study would involve a more rigorous testing of the effect of the Litz wire with higher power, in which all stray wire is replaced by doorbell wire. Furthermore, study into the efficacy of our custom Litz wire versus commercially available equivalents would be very valuable

Acknowledgments

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Sources:
[1] A.V. Peterchev et. al., "A Transcranial Magnetic Stimulator Inducing Near-Rectangular Pulses With Controllable Pulse Width (cTMS)," *IEEE Transactions on Biomedical Engineering*, Vol. 55, No. 1, January 2008
[2] Yi Zhang et. al., "Snubber Considerations for IGBT Applications", International Rectifier Corporation, Applications Engineering