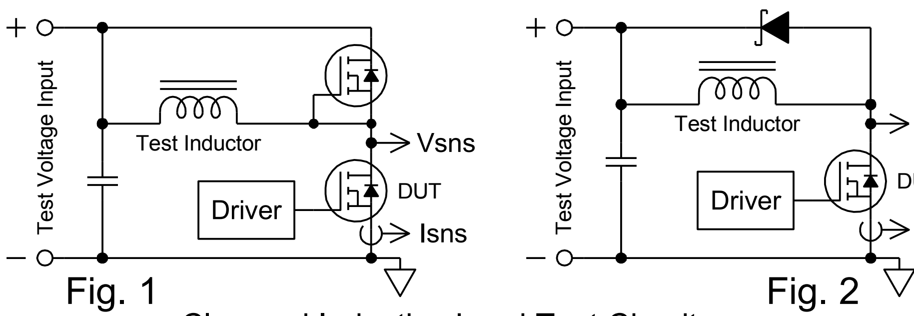
WBGlobalSemi, Inc.

MDPTI White Paper, 2 August 2019

A Modular Inductor for Double Pulse Testing for High Speed, High Voltage and/or High Current WBG Transistors, Bruce Carsten, CTO: Power Circuits and Converters, first half CY 2020.

Application: Flexible, fit for purpose designed inductor for measuring clamped inductive switching speed and switching loss energies of high voltage and/or high current WBG transistors.

The double pulse switching test is the industry standard for measuring clamped inductive load switching times and energy losses in power transistors. This test is used in one of two possible configurations; a half bridge of two identical transistors **(Fig. 1**), or a single transistor with a separate diode clamp **(Fig. 2)**.



Clamped Inductive Load Test Circuits

The half bridge circuit may be used when the transistors are reverse conducting (e.g MOSFET), or when a module contains a reverse conducting diode, in order to measure the characteristics when two such devices are used together in an application. A single transistor may be tested with the fastest available diode, to best measure the switching characteristics of the transistor.

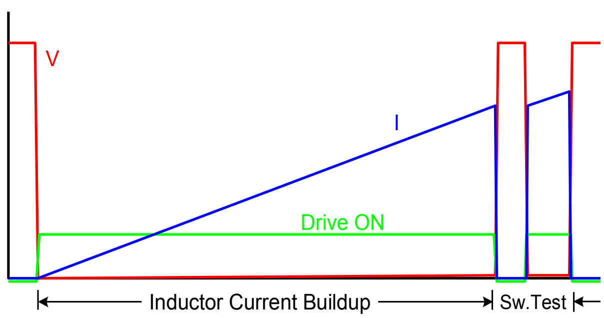


Fig. 3 The "Double Pulse" Test Sequence

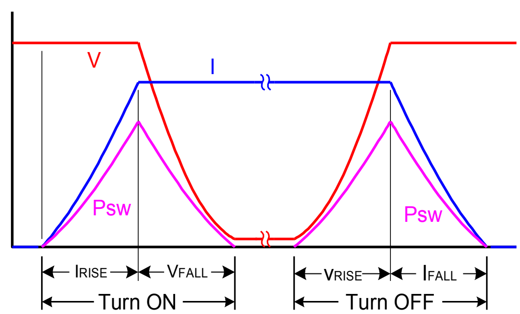


Fig. 4 Clamped Inductive Waveforms

The test sequence is the same in either case. With test voltage applied to the input, the transistor (DUT) is first turned ON **(Fig. 3)** long enough to build up the desired test current in the inductor (the first pulse). The transistor is then turned OFF, and the turn-off time and/or switching energy is measured **(Fig. 4)**. A short time later, after the transistor is fully OFF, it is turned back ON again only long enough to measure the turn-on characteristics, and then back OFF a final time (the second pulse). The stored inductor energy is then dissipated in the inductor's resistance and, to a lesser degree, the forward voltage of the clamp diode(s).

With modern high speed digital oscilloscopes or equivalent, this test usually need only be run once for each test condition, minimizing heating in the transistor, inductor and clamp diode.

Although there are a number of references to double pulse testing, there seems to be little information on suitable inductors, and conventional off-the-shelf inductors are often used in power engineering and research environments. This approach seems to work OK up to 1.2 kV.

However, the inductor design and construction becomes more important and critical as test voltages rise above 1 kV, and when test currents may be 10's or 100's of amps, particularly with switching speeds in the low 10's of ns. 3.3 kV, 50 A SiC MOSFETS are commercial today.

We propose to design and prototype a special, fit-for-purpose modular, double pulse test inductor, with the intent of meeting a wide range of future double pulse test requirements. Any comments or questions should be addressed to carsten@wbgsic.com

Description and Target Specifications:

(1) A modular double pulse test inductor (MDPTI) will consist of a "base" assembly, and one or more inductance modules.

(2) Each module will consist of two "coils", each coil rated for a maximum of 75 amps peak.

(3) Each module of 2 coils will be on the order of 10 x 20 x 2 cm in size, not including any packaging or enclosure.

(4) The design coil voltage will be 3 kV maximum, although lower voltages may be mandated when clamp diodes are used in association with each coil (see (8) below).

(5) The coils of a module may be connected in series or parallel, doubling the net voltage **or** current capability for a module.

(6) Additional modules can be used to increase the voltage and/or current further, up to an estimated 50 kV (TBD).

(7) Each 'coil' will have an inductance on the order of 1 mH, for a peak energy of 3 J/coil. The "first pulse" inductor current charging rate will thus be on the order of: 1 A/us at 1 kV.

(8) Provision will be made to allow incorporation of silicon carbide Schottky clamp diodes (SiC SBDs) into each module, such that the total current and voltage will be shared automatically between the individual diodes, as modules and coils are interconnected in order to scale up the voltage and/or current.

(9) For 1.7 kV SBDs the voltage/coil should be limited to about 1.4 kV.

MDPTI Benefits:

1) An engineer or scientist can start with a base assembly and a single inductance module.
2) Additional modules may be added at any time, to increase the voltage and/or current capability as requirements change.
3) The module coils will have a very high pulse energy density capability, superior to that of silicon steel cored inductors.
4) SiC Schottky clamp diode voltage and current capability scale with that of the MDPTI, allowing testing of future very high voltage transistors using lower voltage SBDs

Technical Focus:

1) Minimization of parasitic MDPTI capacitance, to avoid "swamping out" the output capacitance of smaller, lower current devices
2) Suitable litz wire for low ac winding losses.
3) Sufficient mechanical robustness to tolerate repetitive peak magnetic field forces on the order of 400 N (90 lbs.) between modules.
4) Minimization of external magnetic fields.