Performance and Robustness testing of SiC Power Devices

Student: Asad Fayyaz
Supervisor: Dr. Alberto Castellazzi

Introduction

Silicon Carbide is a new semiconductor material under investigation for Power Electronic applications e.g. Aerospace, oil drilling and railway traction. It has electronic parameters that would enable dramatic improvements in performance. New SiC-based power-switching devices have been demonstrated and experiments are done to confirm the most optimistic performance predictions stated. But still difference exists between the prototype devices that have been demonstrated and establishing an economically functional commercial device. Three important properties to consider while measuring the performance of a power-switching device are:

- Switching frequency
- Junction temperature
- Voltage rating and Power Density

Designed test circuit can be used for the following three types of testing in order to measure the robustness of power-switching devices:

- Double Pulse Tester
- Short Circuit
- Avalanche Breakdown

These three testing types are comprehensive and require different temperatures 25°C – 150°C.

Methodology and Test Hardware Circuit

- Experimental Setup
  - Double pulse generator generates double pulse signal that feeds into the base drive circuit. Width of each pulse is adjustable. Delay between the two are adjustable too.
  - Collector current and collector-emitter voltage waveforms obtained using oscilloscope.
  - Double pulse tester is the main circuit. It also included base drive circuit to drive the base of device under test (D.U.T) which in this case is BJT.
- PSpice Circuit Schematics
- Experimental Circuit
  - Base Drive Circuit was mounted on top of the double pulse tester circuit.
  - D.U.T and diode intentionally placed at the side of the circuit board to allow changing temperature using hot plate.
  - Current Probe mounted on board to allow ease in measurement.
  - Printed circuit board minimizes parasitic inductance.

Circuit Operation, Results and Discussion

- Double Pulse Tester Circuit Operation
  - To test the switching characteristics of the device.
  - An inductive load buck converter which has one device under test (D.U.T), two load inductors and a free wheeling diode. See Fig. 2 and 3.
  - Two pulse signal sent to the base of the D.U.T at one time.
  - Inductor current is charged to the desired value during the first pulse. The falling edge of this pulse and the rising edge of the second pulse correspond to turn-off and turn-on switching transients of the D.U.T. at any desired current and voltage level.
- Results
  - Testing was done at 150V DC and D.U.T was subjected to different temperatures (50°C, 75°C, 100°C and 125°C) using the hot plate.
  - Experimental results match the simulation results.
  - Small amount of current overshoot during turn on due to parasitic inductance.
  - Inductor current increases linearly when the BJT turns ON while BJT is OFF, no current flows through the inductor.
  - Stable device operation over a range of temperatures 50°C – 125°C.
  - 1st current peak at 1.5A and 2nd current peak at 3A.

Conclusion and Future Work

It was a great experience working on SiC switching devices. It is a new semiconductor in the field of power electronics. A lot of research is going on to actually prove that SiC can withstand high voltages, junction temperatures and switching frequency. SiC could also help reduce the size of power electronic devices as SiC devices have higher switching frequency. This research placement work could be extended by using SiC MOSFET and SiC JFET instead of SiC BJT as the device under test (D.U.T). Two SiC switches could be implemented in parallel to study power sharing. This circuit is designed to be able to withstand a maximum voltage of 500V DC so tests could be carried out at 270V and 415V DC. Short circuit technique and Avalanche breakdown techniques can be also carried out using this circuit. This circuit gives an optimum design and ease of use.

Acknowledgements

I would like to extend my deepest gratitude to Dr Alberto Castellazzi for his guidance and support throughout the period of this research placement. Thanks is also due to Mr. Rod Dykeman, Mr. Paul Moss, and Mr. Colin Blackburn for all their support and help with my circuit design and construction.