MOSFET Characteristics at Cryogenic Temperatures

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Abstract

Efficiency is a large concern in power electronics but size and weight must be taken into consideration as well. Power devices in need of thermal sinks for appropriate performance will affect both size and weight. MOSFET devices are the main components in the power electronics world because of their characteristics in power loss and switching performance. The objective of this research is to obtain results as to how the MOSFET device will perform in various temperatures that go as low as liquid nitrogen temperatures. More than one device was tested and compared in order to get the best performing. It is believed Cryogenic operation of MOSFET devices results in improved performance and efficiency. The switching performance of the devices will be analyzed using the Double Pulse Test (DPT). Ultimately, the objective of this research is to design a DC-AC inverter for Boeing & NASA aircraft using the best performing MOSFET device.

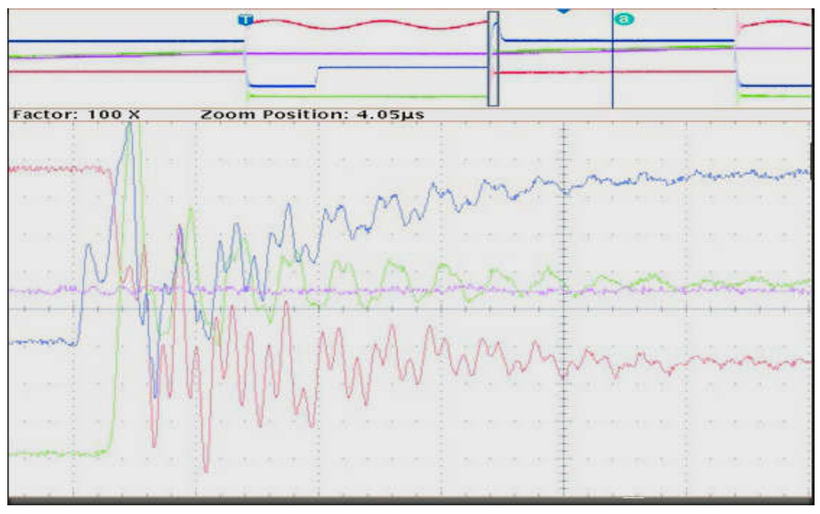


Figure 1: Switching Transient using DPT

Schematics

There are four main characteristics that are being observed for each device. Each defines the device's efficiency and performance. On-state resistance, switching loss, body diode, and breakdown voltage are the four characteristics that will be affected by the change in temperature and determine the device performance gains. Different configurations and set up are used on the devices to analyze each characteristics. The figures below show the schematic for each test.

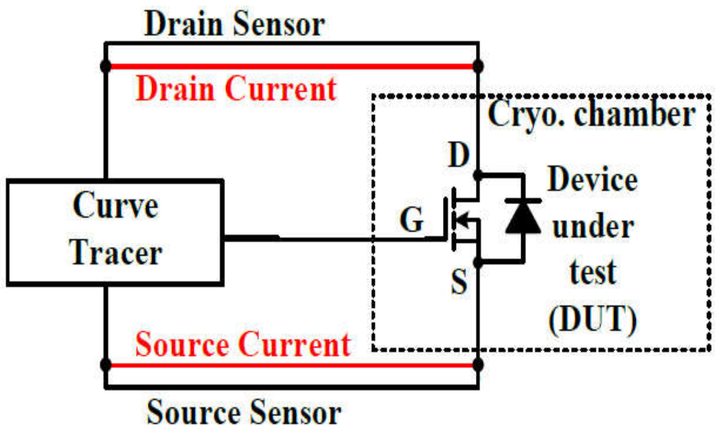


Figure 2:On-state resistance and body diode testing configuration.

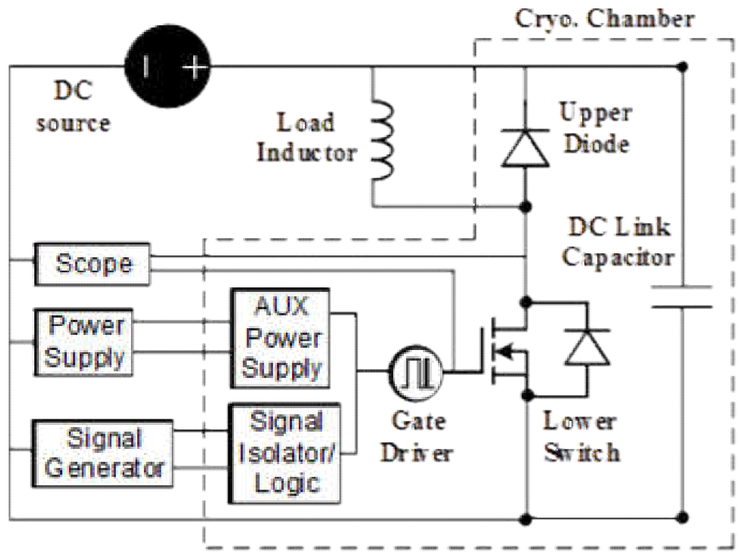


Figure 3: Switching Performance Testing Configuration

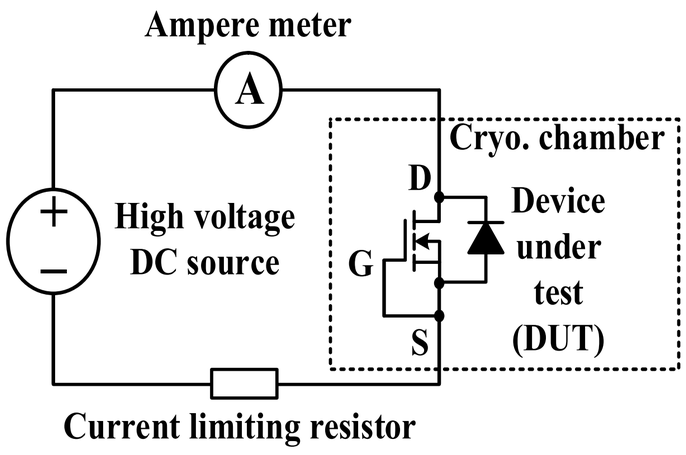


Figure 4: Breakdown Voltage Testing Configuration

Results

These testings consist of devices designed by different manufacturers (Microsemi, Infineon, IXYS). The following figures are plots from one of the devices being tested (Infineon) and correspond to the configurations from above.

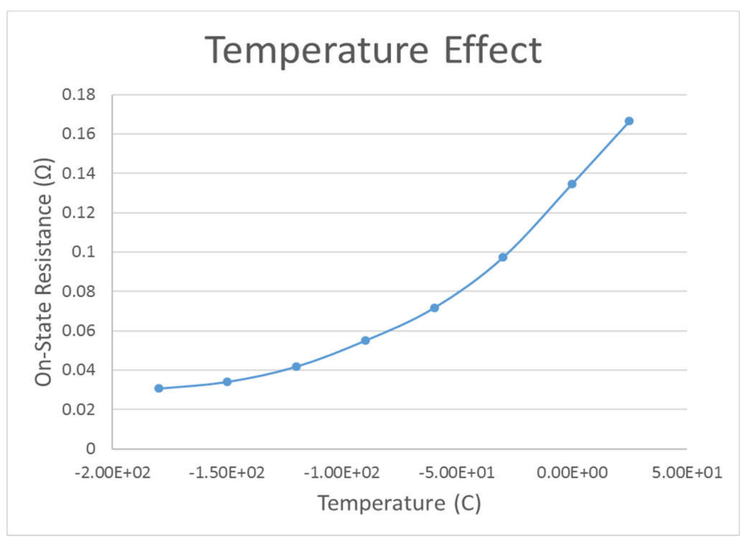


Figure 5: On-state Resistance

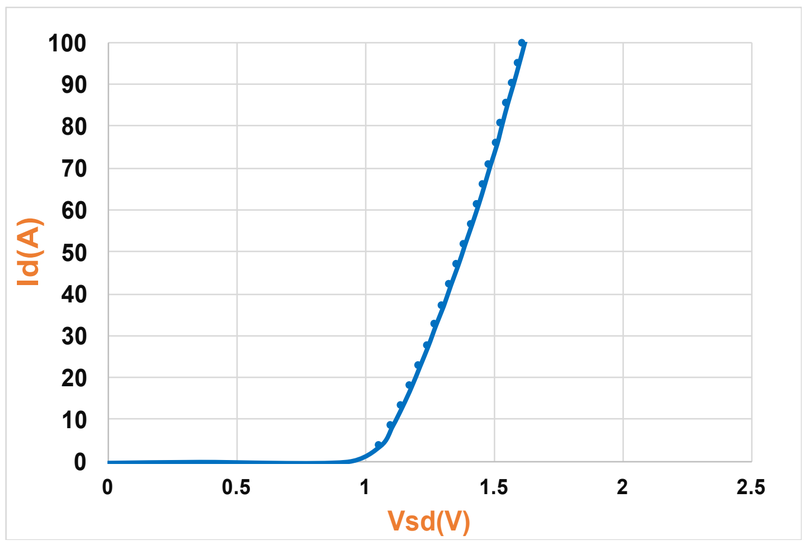


Figure 6: Body Diode

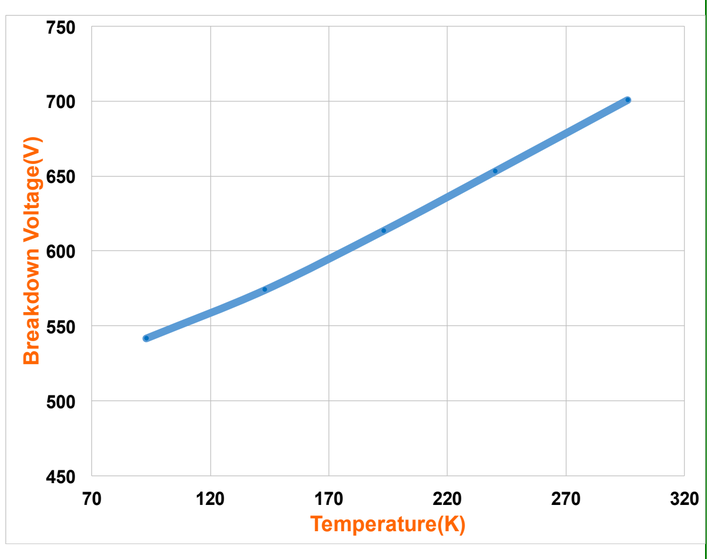
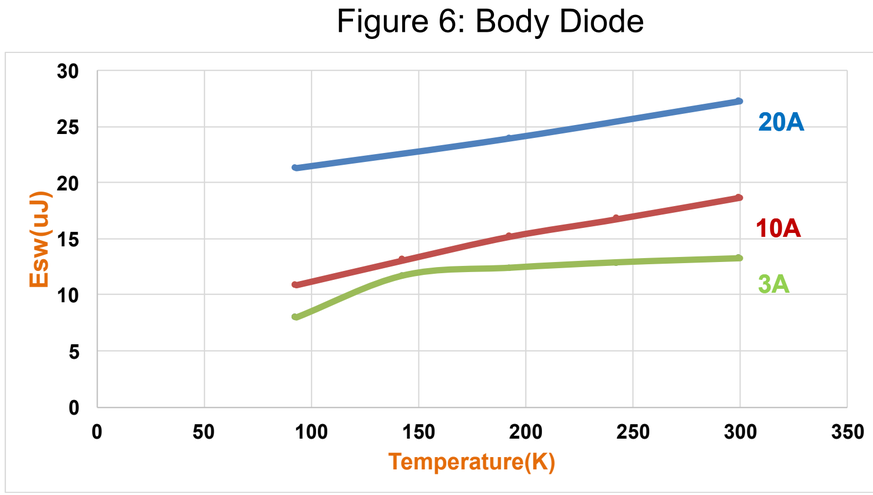


Figure 7: Breakdown Voltage

Figure 8: Switching Losses



Conclusion

This research demonstrates a way to reduce the losses in power MOSFETs. This allows for more efficient power devices with many advantages when operating at cryogenic temperature. MOSFET devices have switching characteristics that will have losses at high frequencies. Under low temperatures, the devices have slightly faster switching with less ringing, which is caused by internal parasitic as earlier stated. On-state resistance drastically decreased due to the increase of carrier mobilities in the MOSFET's main resistive components. These factors allow the efficiency of the device to increase and enhance its performance at cryogenic temperatures.

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