24KA DC Energy Extraction Switch for LARP Magnet Testing at BNL

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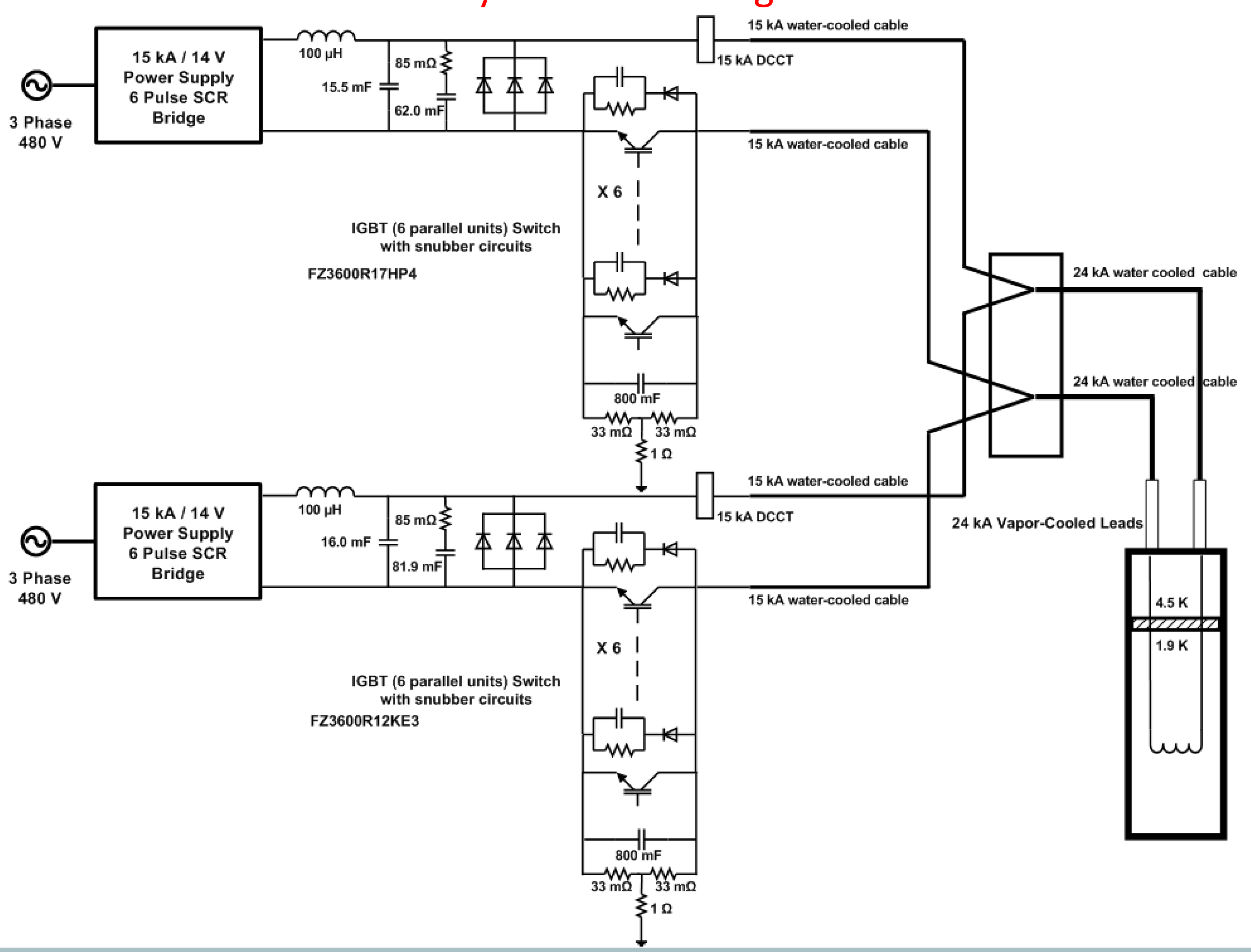
HiLumi HL-LHC PROJECT

Abstract

The high luminosity upgrade of the Large Hadron Collider (LHC) at CERN will consist of Nb_3Sn based superconducting magnets operating at about 22kA DC. When these magnets quench, the power source has to be disconnected and stored energy should be discharged into a dump resistor very quickly. For this purpose, a 24kA DC current interruption switch based on Insulated Gate Bipolar Transistors (IGBT) has been developed. As opposed to Thyristor or mechanical switches which take milliseconds to interrupt the current, an IGBT based switch interrupts the current in microseconds. The switch is realized by paralleling twelve 3600A IGBTs. Paralleling of high current IGBTs made from different batches of silicon and of different voltage ratings is a challenging task. This paper discuss techniques developed to synchronize the turn off of twelve 3600A IGBTs made by Infineon Inc. Techniques developed pertain to gate charge control, snubber design, steady state and transient current sharing, stray inductance and thermal management.

System Block Diagram



Component used

Bank 1: Six IGBTs model FZ3600R17HP4 each with gate driver made by AgileSwitch Inc. model HPFM - 00143

Bank 2: Six IGBTs model FZ3600R12KE3 each with gate driver made by Concept model 1SD418F2

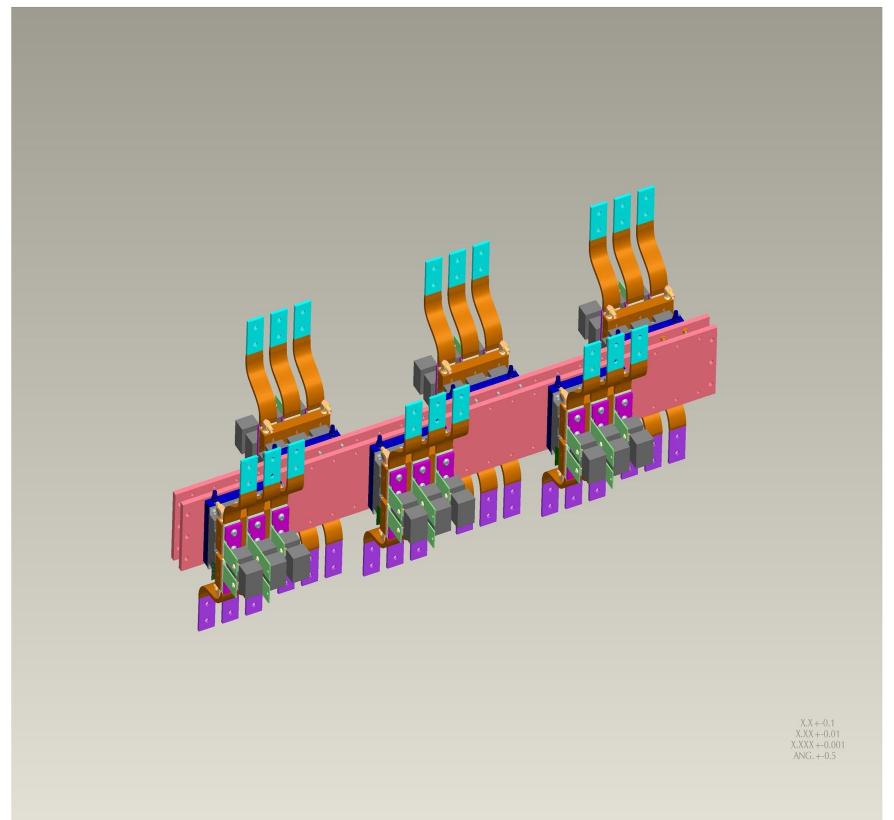
Snubber for each IGBT: 6x30uF, 1250V capacitor, 500K resistor, Fast turn off diode IXYS DSP13-12AR.

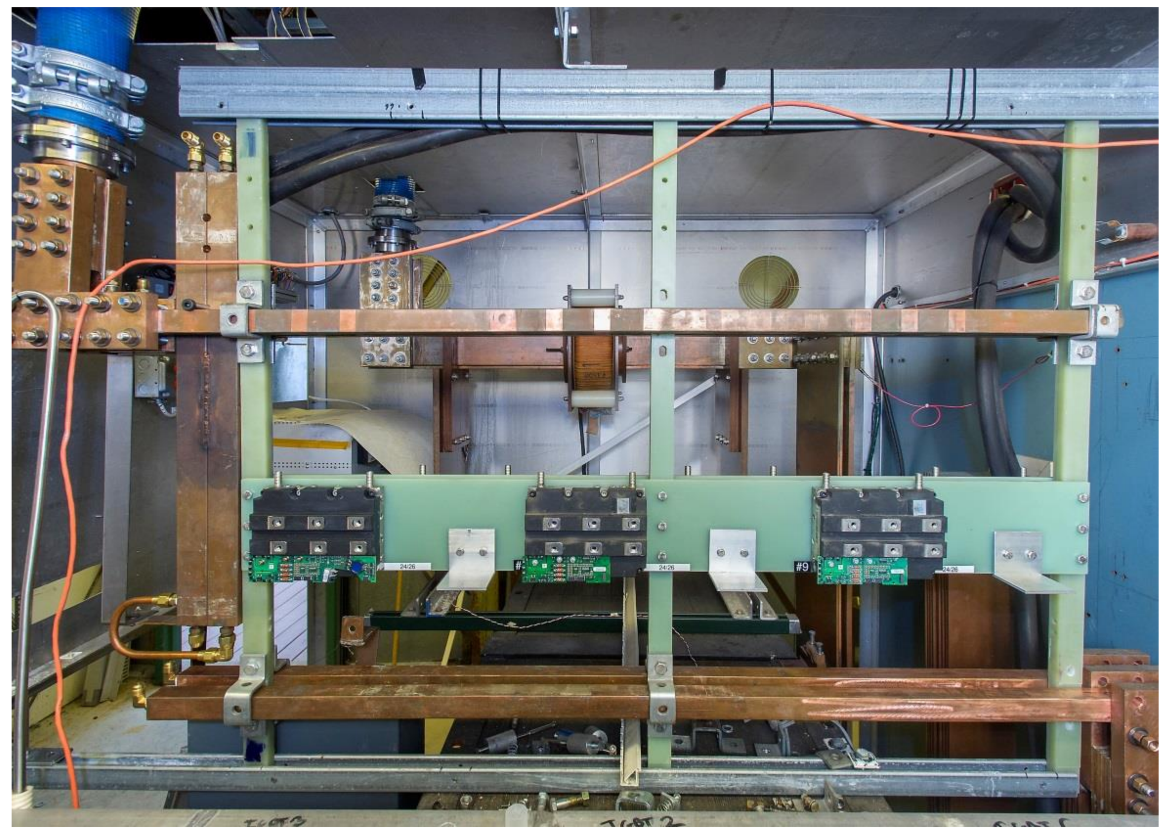
Snubber capacitor across collector emitter bus: 800mf, 2KV

National Instrument make cRIO DAQ for fast and slow data capture.

LabView based control and monitoring program

Assembly





Critical Considerations

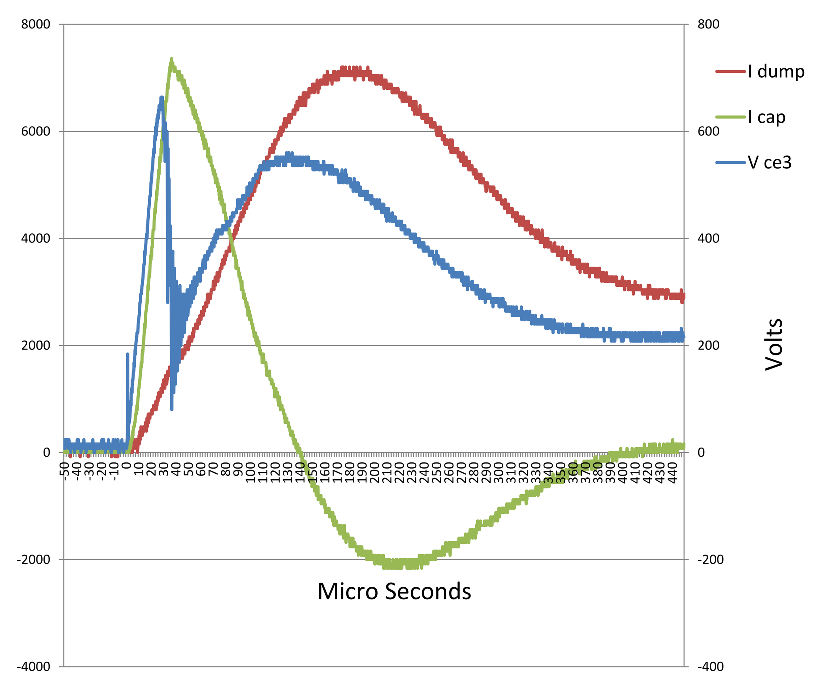
Paralleling multiple high current IGBTs poses many challenges. Three main factors are 1) Static current sharing; 2) Dynamic current sharing and 3) Synchronization of turn ON and turn OFF.

The equal sharing of static current of about 2000A in each IGBT was achieved by mechanical design which presented same DC resistance in the current path of each IGBT. Dynamic current sharing was achieved by unique mechanical design which presented equal and minimum stray inductance in current path of each IGBT. The distance between locations of each IGBT was designed to minimize mutual inductance between neighboring IGBTs.

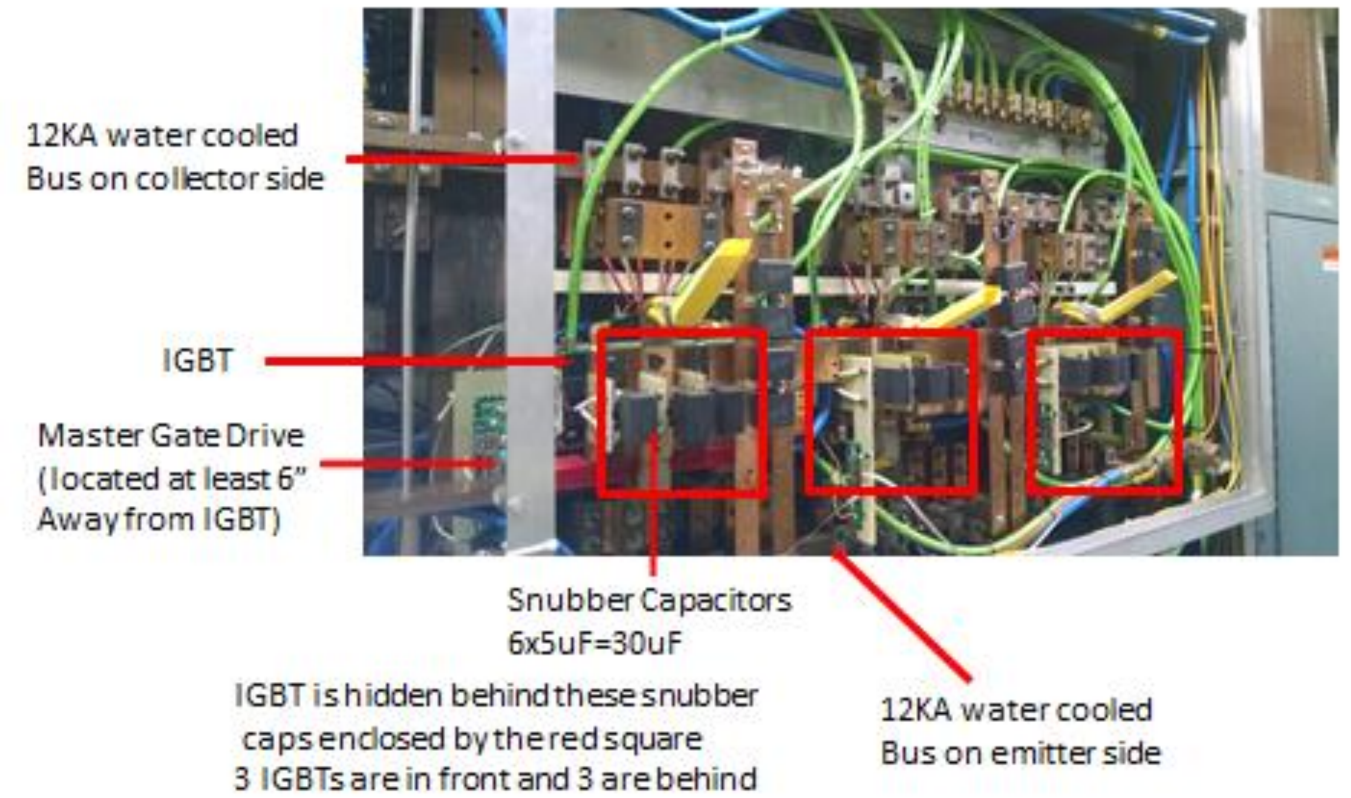
The most difficult part is the synchronization of switching time. In this application all IGBTs are turned on at zero current at the start of current ramp, so turn ON synchronization is not very important. Turn OFF synchronization is very important because discharging magnet will push full current through the IGBT which has delayed turn OFF. This can overheat and destroy the IGBT. The turn OFF time were synchronized and tuned by trimming the gate resistor R_G on the driver board to match gate capacitance of each IGBT.

By employing symmetry in mechanical design and trimming gate resistances, paralleling of twelve high current IGBTs was achieved.

Voltage at Turn OFF- 18500A

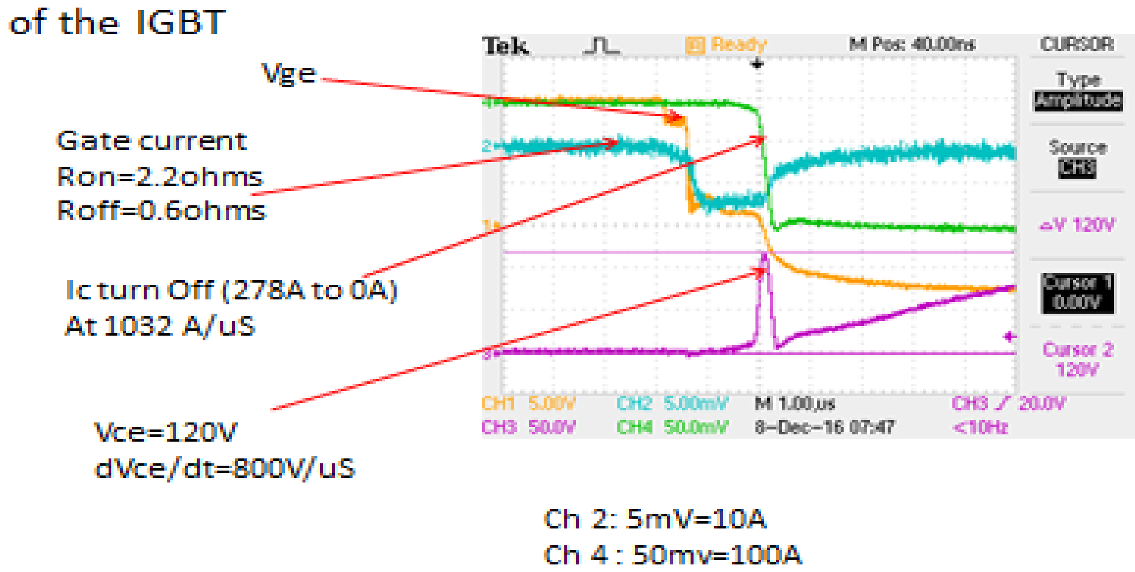


Complete Assembly with cooling water pipes and capacitors

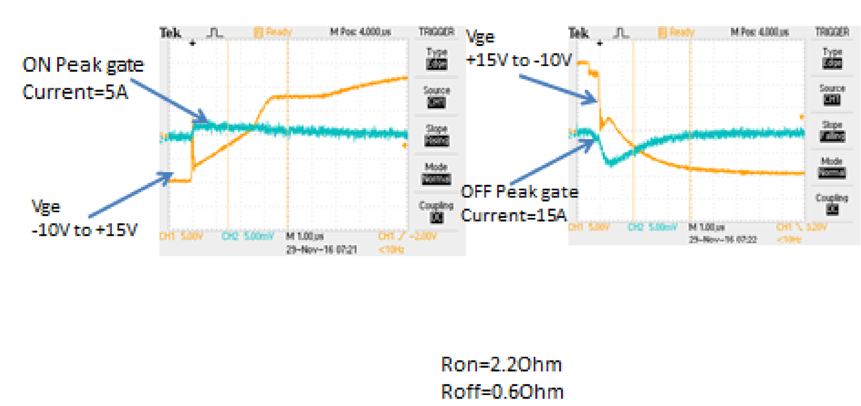


10000A Shut Off

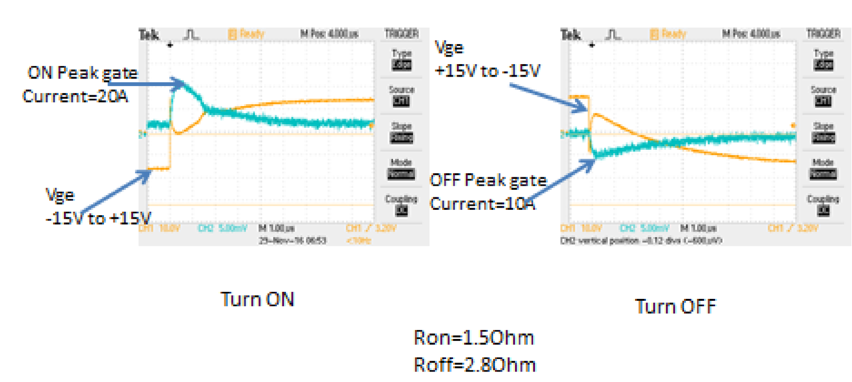
Current thru each IGBT is10000/12=834A. Current thru each element of IGBT FZ3600R12KE3 is 834/3=278A. This current is measured using Ragowski coil around one of the collector terminal of the IGBT



Gate Driver: Agile part # HPFM-00143
IGBT : Infineon part # FZ3600R12KE3



Gate Driver: Concept part # 1 SD536 F2
IGBT : Infineon part # FZ3600R12KE3



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Presented at the 25th International Conference on Magnet Technology , 2017 Aug 28-Sept 1. Amsterdam, Netherlands; Session: Thus-AP-PO4