Demonstrating Reliability of Murata DC-DC converters in IGBT/MOSFET gate drive applications

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ABSTRACT

Low power DC-DC converters such as those recently released by Murata Power Solutions can be used to generate the power rails for óhigh sideô IGBT or MOSFET switches used in high power bridge circuits. University laboratory testing shows that these converters can withstand the extreme common mode voltages present in the application with good margin and for extended periods.

PAPER

Many applications of IGBTs or MOSFETs in bridge circuits require galvanic isolation between device gate drives and system ground. For óhigh sideô devices the gate drive circuit is offset from ground by a continuously switched high voltage typically up to 1.2 kV at more than 10 kHz with rise and fall times measured in nanoseconds. Simple transformer coupling of the PWM signal to the gate is feasible but at higher power and when control and monitoring is necessary, opto-couplers feeding powered gate drivers are normally used. Small DC-DC converters such as the MGJ series recently released by Murata Power Solutions provide optimum power rails for the gate drivers and are designed to withstand the high common-mode ódV/dtô between their input and outputs in this application.

The MGJ series consists of MGJ2, MGJ3 and MGJ6 with 2, 3 and 6 Watt rating respectively. MGJ2 is through-hole and suitable for DC link voltages up to around 1.5 kV whereas the MGJ3 and 6 are surface-mount parts and suitable for DC links of at least 2.5 kV. All ranges have variants suitable for powering gate drives for IGBTs, SiC, GaN and silicon MOSFETs.

Extensive qualification testing at Murata showed that these converters easily withstand continuous high isolation voltages in excess of 5 kVDC but the effect of high common-mode voltage at high frequency seen in real applications was hard to predict and quantify. Particularly, potential slow degradation of insulation due to partial discharge effects was of concern given the typical high value, long life target applications. Partial discharge causes progressive breakdown of micro-voids in insulation leading to eventual total failure after sometimes extended periods. It was decided therefore to commission the Electrical Systems and Optics Research Division at Nottingham University in the UK to design and implement experiments to characterise the reliability of the Murata DC-DC converters powering gate drives of IGBTs and SiC MOSFETs under extreme conditions in real applications.

An initial consideration was how to measure any degradation. Obviously converter failures would be an indication but to identify progressive effects, in addition to traditional óhi-potô tests, 3D X-ray Tomography imaging was planned before and at regular periods during the experiments. Figure 1 shows a typical X-ray screenshot of the barrier in an MGJ converter.

To apply the parts in real applications, test rigs were constructed to enable the converters to power gate drives to IGBTs and SiC MOSFETS in a ótwo device inverter legô configuration shown in Figure 2. This topology is common in most 2-level inverter based motor drives at 240/415 V mains voltages. The switches were driven by opto-coupled signals at fixed frequency up to 100 kHz and fixed duty cycle with about 1 us dead time. The óDC linkô voltage was variable up to 3 kV. To enable removal for test at stages during the experiments, the DC-DC converters were assembled to plug-in modules shown in Figure 3.

Loads were not applied to the inverter during testing of the DC-DC converters to reduce stress on the IGBT and SiC devices and to enable the fastest dV/dt across the drive circuitry. Highest values achieved were in excess of 80 kV/µs.

To simulate worst-case, real assembly conditions, surface mount MGJ3 and MGJ6 devices were pre-conditioned to procedure IPC/JEDEC J-STD-020D1. Conditions were 24 hours at 125 °C followed by 168 hours at 85% relative humidity and 85 °C followed by three reflow cycles at 245 °C peak.

For the IGBTs, typical IXYS devices were chosen running at 20 kHz and initially with a DC link voltage of 1600 V, close to the IGBT maximum rating. Observed dV/dt across the DC-DC converter was greater than 80 kV/µs, much faster than would normally be seen in real applications. For the SiC devices, CREE parts were selected and run at 100 kHz with a DC-link voltage of 1600 V showing a dV/dt of more than 60 kV/µs. All three variants of the DC-DC converter parts were then allowed to run over an extended period with periodic inspection of the insulation by hi-pot test and 3D X-ray tomography.

1600 V is currently the maximum feasible DC link voltage for SiC MOSFETs from CREE with 1700 V rating but to explore higher voltages with IGBTs, further tests are being conducted with a DC link of 3 kV with an IXYS device rated at 4000 V with gate drives powered by MGJ3 and MGJ6 DC-DC converters. Contact Murata for latest test results.

A summary of test conditions is given in Table 1

Table 1.

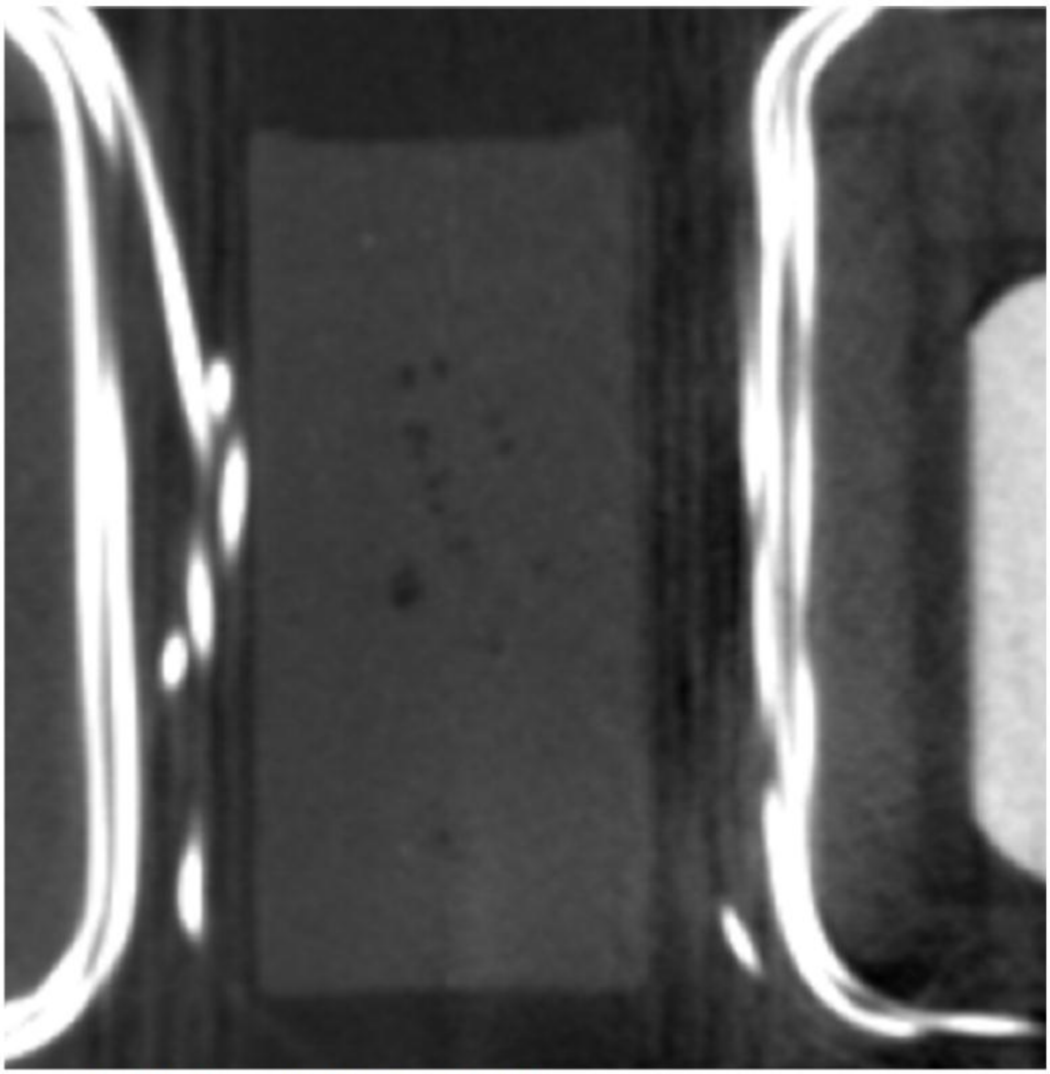
DC-DC Converter	Switch Devices	Type	Inverter Frequency	DC Link Voltage	dV/dt	Test Duration
MGJ2D121509SC	CREE-C2M1000170D	SiC	100kHz	1600V	>65kV/us	>2200 Hours
MGJ3	IGBT - IXGH6N170A	IGBT	20kHz	1600V	>80 kV/µs	>2200 Hours
MGJ3	CREE-C2M1000170D	SiC	100kHz	1600V	>60kV/µs	>2200 Hours
MGJ6	IXGH6N170A	IGBT	20kHz	1600V	>80 kV/µs	>1000 Hours
MGJ6	CREE-C2M1000170D	SiC	100kHz	1600V	>60kV/µs	>2200 Hours
MGJ3/6	IXEL40N400-ND	IGBT	-	3000V	>20kV/ µs	Starting

No functional failures of the DC-DC converters have occurred during a total of more than 9000 hours of testing across all conditions. 3D X-ray tomography has also showed no signs of degradation of the insulation materials. Results so far are very encouraging given the levels of stress applied to the DC-DC converter insulation, particularly dV/dt, leading to good confidence that the parts will be reliable in real applications. To increase confidence still further, tests are ongoing to accumulate more device-hours, the results of which will be published in due course.

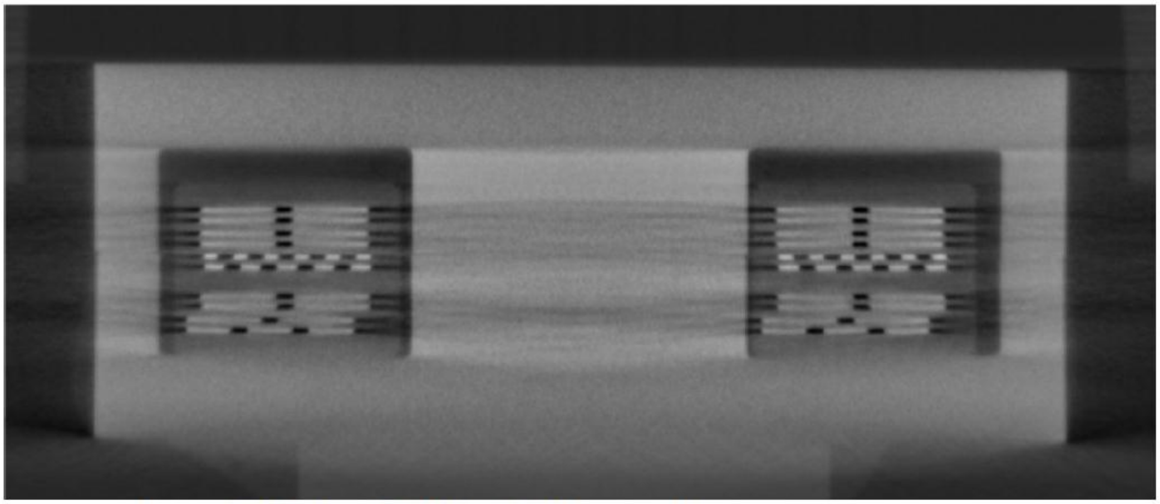
As well as data sheets for the MGJ series of DC-DC converters, Murata has published application notes and a white paper discussing the issues in selecting appropriate converters for given switching devices. An EXCEL based selection tool is also available. Contact Murata for further details.

The Electrical Systems and Optics Research Division at Nottingham University with 100 plus members is one of the largest groups worldwide researching latest techniques in the fields of power conversion, motor and machine control.

Figure 1. Example X-ray images of converter insulation barrier.



Example 3D slice of MGJ2 at 1000 hours testing



Example 3D slice of MGJ3 at 500 hours testing

Figure 2. Test arrangement

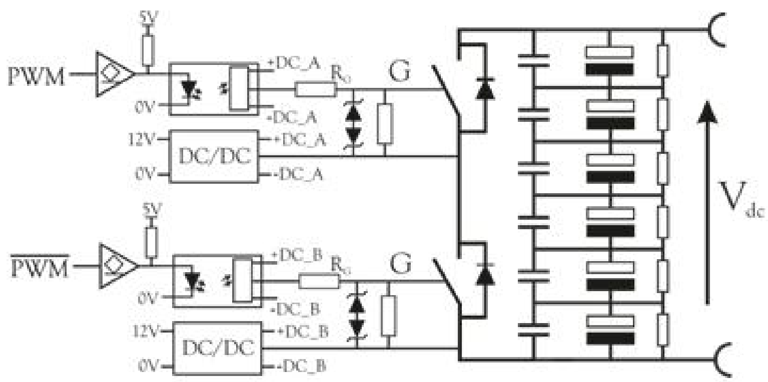


Figure 3. MGJ6 DC-DC converter on its removable carrier