Testing Integrated COTS DC/DC Converters in Hostile Environment

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Abstract

We have irradiated three types of integrated COTS DC/DC converters with a ^{60}Co γ-source at different dose rates, 5, 10 and 22 Gy/h in Si, up to about 4 kGy. During the test they were biased and loaded, and remotely monitored. After the irradiation, we performed a room-temperature annealing for two weeks keeping them biased and monitored, followed by another short-period irradiation. Two of such converters were also tested in a static B field up to 1 T.
We have also built a DC/DC converter with GaN devices in the final stage, testing it under γ-rays together with all other converters, and in a static B field.
Results shown here, combined with the ones obtained by the Michigan team led by Dante Amidei, with which we are collaborating, demonstrate that most of the tested DC/DC converters could work in a highly hostile environment, like the one in which the ATLAS New Small Wheel (NSW) detector will operate after the phase 1 upgrade.
COTS and custom DC/DC converters are now under test in a fast neutron facility. Irradiation with protons and heavy ions will follow in the next months.

The DC/DC converters – Irradiation test setup

LTM 4619
- Specifications: V_{in} up to 26.5 V – V_{out} from 0.8 V to 5 V - Two independent outputs, 4 A each (5A peak) – Power Good monitor
- Test setup: two irradiation periods with two devices each one. V_{in} = 24 V, $V_{out1,\ ch1\&2}$ = 1.8 V, $I_{out1,\ ch1\ \&2}$ = 3.1 A; $V_{out2,\ ch1\&2}$ = 3.3 V, $I_{out2,\ ch1\&2}$ = 3.6 A, measured efficiency 68% for both devices

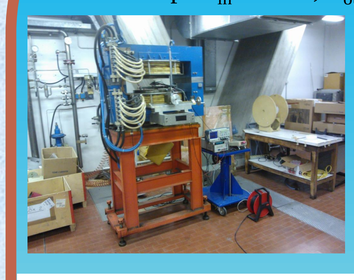
LTM 8033
- Specifications: V_{in} up to 36 V – V_{out} from 0.8 V to 24 V – One output, 3 A – Power Good monitor
- Test setup: one irradiation period with two devices. V_{in} = 24 V, V_{out1} = 1.5 V, I_{out1} = 1.8 A; V_{out2} = 3.3 V, I_{out2} = 1.9 A, measured efficiencies 80% for device 1 and 58% for device 2

LT 8610
- Specifications: V_{in} up to 42 V – V_{out} from 1.8 V to 12 V – One output, 2.5 A – Power Good monitor
- Test setup: one irradiation period with one device. V_{in} = 24 V, V_{out} = 1.5 V, I_{out} = 2 A, measured efficiency 83%

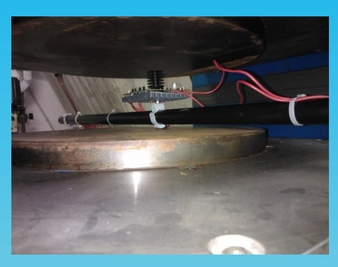
Custom PoL with GaNs
- Specifications: V_{in} up to 19 V – V_{out} from 0.6 V to 5.5 V – One output, 10 A
- Test setup: one irradiation period with one device. V_{in} = 12 V, V_{out} = 1.2 V, I_{out} = 6 A, measured efficiency 68%

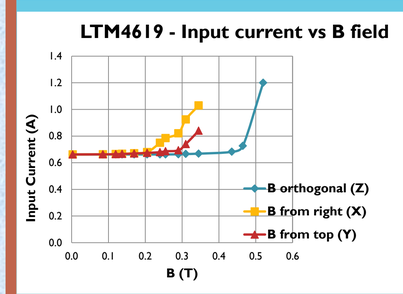
B field tests - Results

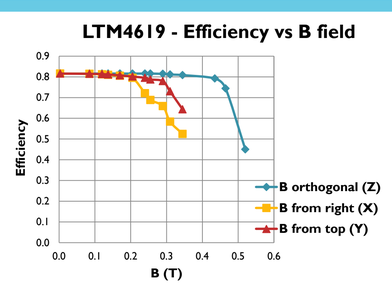
LTM 4619
- Test performed at LASA – INFN Milano on one device, rotating it along the three coordinates
- Setup: V_{in} = 20 V, $V_{out1\&2}$ = 1.8 V, $I_{out1\&2}$ = 3 A.

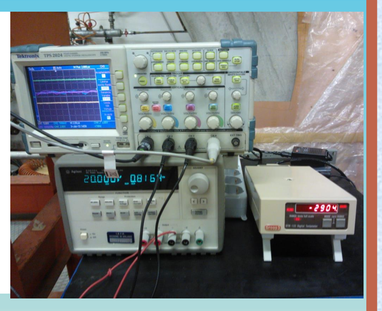


The dipole magnet used for the test (left) and the demo board positioned inside its polar expansions (right). The black rod on which the board is mounted serves for rotating it along the three coordinates



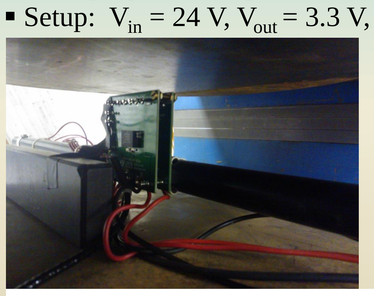




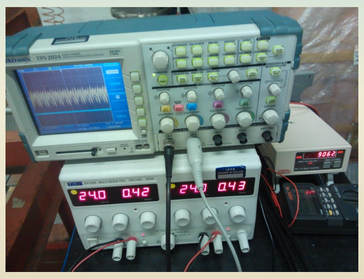


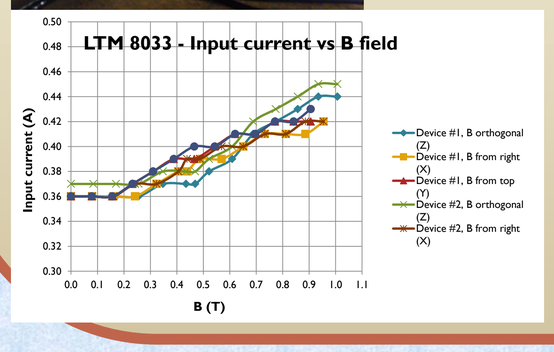
Output ripple was about 0.5 V at B = 0.29 T along X

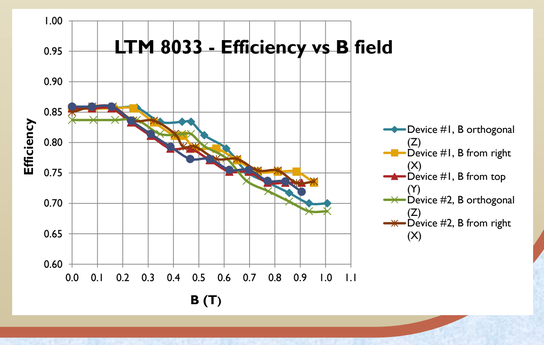
LTM 8033
- Test performed at LASA – INFN Milano on two devices, put one on top of the other. They were rotated as a single piece along the three coordinates
- Setup: V_{in} = 24 V, V_{out} = 3.3 V, I_{out} = 2.5 A.



The two boards inside the magnet (left). Output ripple was about 30 mV at B = 0.9 T along Y, and about the same value for the other two coordinates



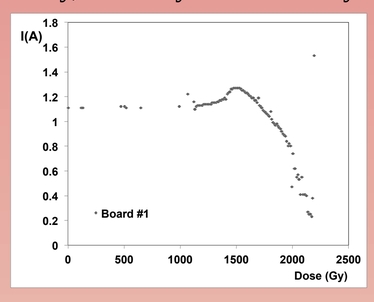


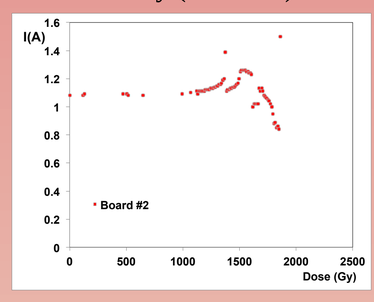


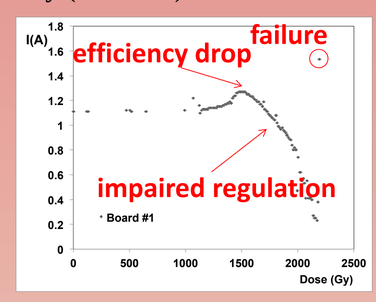
Irradiation tests - Results

Two irradiation campaigns were performed at the Calliope ^{60}Co source facility in ENEA Centro Ricerche Casaccia (Roma). During the first period we irradiated two LTM 4619 with a dose rate of 22 Gy/h in Si, during the second period we irradiated two LTM 4619, using different devices with respect to the first period, two LTM8033 and one Custom PoL with GaNs with a dose rate of 5 Gy/h in Si. In the same period we also irradiated one LT8610 with a dose rate of 10 Gy/h in Si. All devices were annealed at room temperature for two weeks after the irradiation, with V_{in}, I_{in} and V_{out} parameters continuously monitored. After the annealing period, devices were again irradiated for some hours.

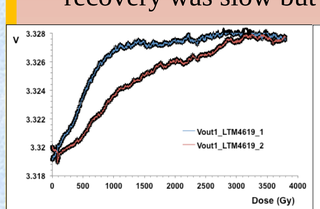
LTM 4619
- First irradiation, 22 Gy/h. Only I_{in} was monitored. Both devices had some current peaks beyond 1 kGy, then they unrecoverably failed at 2.3 kGy (board #1) and 1.85 kGy (board #2).

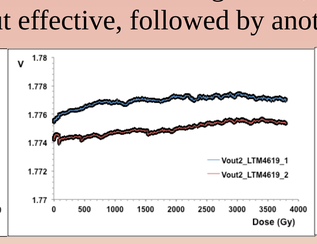


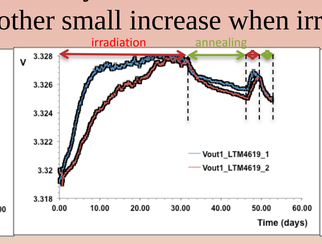


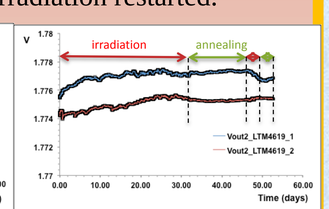


- Second irradiation, 5 Gy/h. Integrated dose was 3750 Gy. V_{out} was stable at per mil level. Efficiency was 68% ± 0.01 for both devices. First two plots from left show V_{out1} and V_{out2} for both devices, the other two plots represent the annealing effect, clearly visible for the two outputs ar 3.3 V. The recovery was slow but effective, followed by another small increase when irradiation restarted.



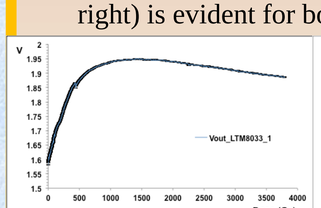


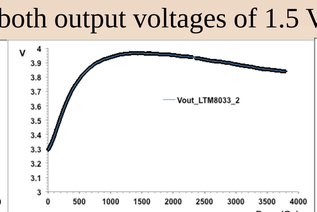


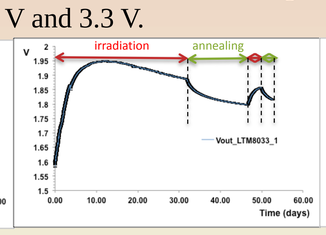


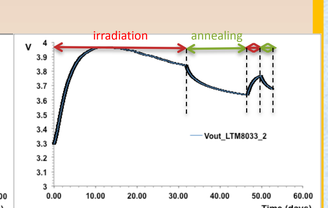
LTM 8033

Same conditions than above. V_{out} increased by 25% (board 1) and 20% (board 2). Efficiency was 80% ± 0.03 for the first device and 58% ± 0.04 for the second. Annealing effect (the two plots on the right) is evident for both output voltages of 1.5 V and 3.3 V.



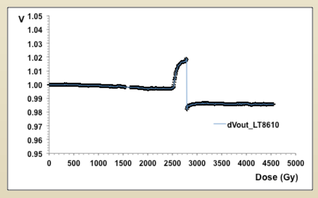


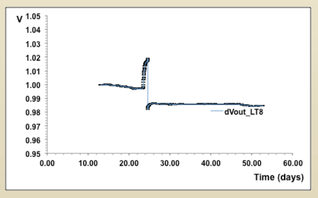




LT 8610

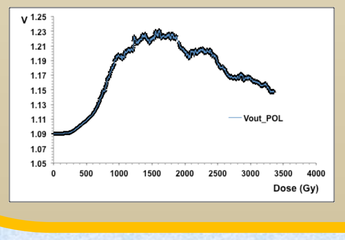
Dose rate of 10 Gy/h, integrated dose up to 4000 Gy. V_{out} showed a glitch of about 5% after 18 days of irradiation, otherwise is stable at the level of per mil. This glitch happened during a weekend, without any presence of persons interfering with the setup.

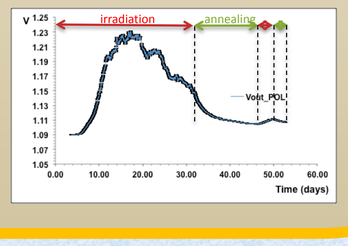




Custom PoL with GaNs

Dose rate 5 Gy/h, integrated dose 3300 Gy. V_{out} increased by 13%. Efficiency was 68% ± 0.02. Recovery during annealing was almost completed, as shown in the above plot. The subsequent damage due to the short final irradiation is practically negligible.





Conclusions

We have irradiated four different COTS DC/DC converters with a ^{60}Co source. Two of them, the LTM 4619 and the LT 8610, showed practically no output voltage variations when irradiated with a sufficiently low dose rate, 5 Gy/h the first and 10 Gy/h the second. The other two had variations up to a maximum of 25%. Devices worked fine up to the integrated doses reached in the campaign, 3.3 kGy (the custom PoL), 3.75 kGy (the LTM 4619 and LTM 8300) and 4 kGy (the LT8610). Room-temperature annealing lasted two weeks, simulating the conditions of a standard LHC shutdown, and evidenced a good recovery of the output voltages, when changing during the irradiation. A successive short-time irradiation showed a small increase of the temporary damage of the devices.
Two of such devices were tested in a static B field. One of them, the LTM 8033, performed quite well up to 1 T in all three coordinates. The LTM 4619 was able to work up to 0.45 T along one coordinate, but no so well along the other two.