The irradiation test of LDOs for the ALICE FoCal detector at LHC

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A new forward calorimeter (FoCal)[1] with a unique capability to measure the direct photon production at the forward rapidity will be installed in the ALICE experiment[2] during the next LHC Long Shutdown and it is expected to acquire the data in the period of 2029-to-2032. FoCal is approximately 1 m^3 in size and comprises a Si + W electromagnetic component with longitudinal segmentation (FoCal-E) and a Cu + Scintillating-fiber hadronic component (FoCal-H).

We developed the FoCal-E prototype with 18 low- and 2 high-granularity layers using silicon pad and pixel sensors, respectively. It exhibited longitudinal shower profiles at the CERN PS/SPS complexes and a good signal-to-noise ratio for the MIP measurement at the Tohoku Univ. ELPH test beam line. The HGCROC V2 ASIC[3] known as a radiation hardness device was used as the front-end electronics for the low-granularity layers. Two stable power sources of 1.2 V were needed for the analog and digital circuits in the HGCROC V2 ASIC, and two low-dropout linear regulators (LDOs) were mounted on a printed circuit board (PCB) with the HGCROC V2 ASIC.

The radiation tolerance of LDOs must be studied because FoCal will be placed in the hard-radiation area around the LHC beam pipe in the ALICE cavern. According to a simulation result, FoCal including the front-end electronics will have approximately 7×10^{13} 1 MeV neuron equivalent per cm^2 at the maximum. We obtained 7 types of LDOs from 5 manufacturers which met the requirements for the HGCROC V2 ASIC over the shortage of semiconductor devices. We conducted the irradiation test of the LDOs, together with the silicon pad sensors, at the RANS (RIKEN Accelerator-driven compact neutron systems) in 2023.

Figure 1 shows the tested LDOs on PCBs. Certain LDOs were mounted with capacitors because it was difficult to obtain a stable output voltage without capacitors in pre-tests. We developed the GP-IB-based automatic test system to measure the output voltages of the LDOs with resistive loads through 3 m parallel cables continuously. The recorded data also indicated that a temperature in the RANS target equipment was maintained at approximately 23.6°C.

The LDOs were irradiated by the neutron beam with 10% of the full intensity for 4 hours and 45 min and with the full intensity for 1 hoursand 30 min in total. The data from the indium foils on the same PCBs with the LDOs indicated that the total radiation doses exceeded 10^{13} 1 MeV neuron equivalent per cm^2. Figure 2 shows the measured output voltages of the LDOs and a time of the day in the vertical and horizontal axes, respectively. Seven samples belonging to 4 types of LDOs

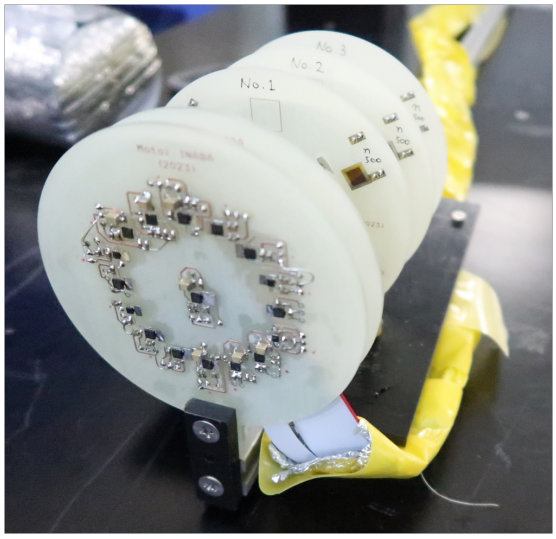

Fig. 1. LDOs from 5 manufacturers were mounted on the 1st and 2nd PCBs and irradiated at the RANS facility.

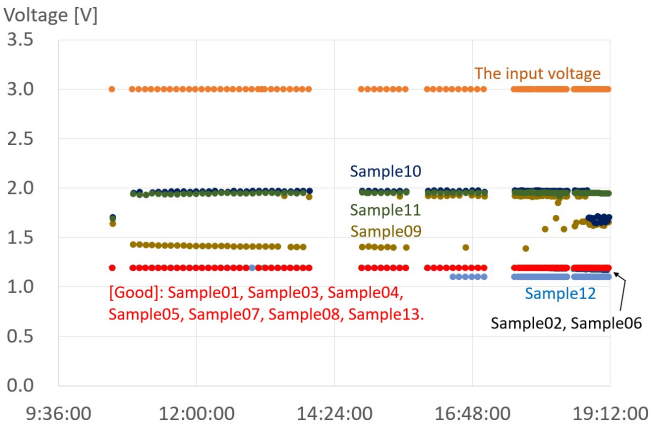

Fig. 2. Output voltages of 7 LDOs maintained at 1.2 V to the end of the irradiation test.

maintained the stable output voltages to the end of the irradiation test. However, the output voltages of other samples suddenly increased or decreased. There was a risk of destroying the HGCROC V2 ASIC when the output voltage of the LDO increased. As a result of the irradiation test, we found new LDOs with a potential of the radiation tolerance and a small package for the front-end electronics of the new ALICE FoCal detector.

References

1) FoCal LoI [ALICE Collaboration], CERN-LHCC-2020-009, LHCC-I-036 (2020).
2) K. Aamodt *et al.* [ALICE Collaboration], J. Instrum. **3**, S08002 (2008).
3) D. Thienpont and C. de La Taille, J. Instrum. **15**, C04055 (2020).

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