Contribution ID: **144** Type: **Poster**

Design and first test results of the CMS HGCAL ECON-T ASIC including an autoencoder-inspired neural network for on-detector data compression

Tuesday, 20 September 2022 16:40 (20 minutes)

The CMS experiment will replace its endcap calorimeters with a High Granularity Endcap Calorimeter (HGCAL) as part of the upgrades for High Luminosity LHC. The HGCAL readout system includes the Endcap Trigger Concentrator (ECON-T) ASIC to help manage the immense data volume associated with the trigger path of this six-million channel "imaging"calorimeter. Each ECON-T ASIC handles 15.36 Gbps of HGCROC trigger data and performs up to 12x data reduction by means of four user-selectable algorithms for data selection or compression. The design and first test results of the ECON-T ASIC are presented.

Summary (500 words)

The HGCAL is a 47-layer sampling calorimeter composed of a front electromagnetic (ECAL) section and rear hadronic section, including both silicon and plastic scintillator as active materials. The trigger readout system consists of the HGCROC ASIC for digitization, the ECON-T ASIC for data reduction, and the lpGBT ASIC for data serialization to 10.24 Gbps. With approximately 6 million readout channels, 10 bits of charge and 10 bits of time information per channel per LHC bunch crossing, the inherent data volume is approximately 5 petabits per second. This volume is reduced to about 300 Tb/s by reading out every other layer in the ECAL section, 4x or 9x ganging of sensor channels into trigger cells (TC) within the HGCROC, and using a 7-bit floating point encoding for each TC. The ECON-T ASIC further reduces the data volume to approximately 40 Tb/s by means of four user-selectable algorithms for data selection or compression, which allows readout of the entire HGCAL trigger path with about 9k optical links at 10.24 Gbps each. The ECON-T ASIC is required to operate in a radiation environment up to 200 Mrad, with power consumption of 2.5 mW per channel (500 mW per ASIC), and latency of 500 ns. The ECON-T algorithms include a threshold algorithm, which reads out TC exceeding a programmable threshold; a super-TC algorithm which combines data from adjacent TC; a ranked-choice algorithm which sorts and reads out the largest TC up to a programmable number of TC; and an autoencoder-inspired, configurable neural network which provides lossy data compression up to 7x. The ECON-T ASIC was fabricated in 2021 as a full functionality prototype. Functionality and radiation testing began in December 2021. The design as well as results of full functionality testing and radiation characterization are presented.

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Session Classification: Tuesday posters session

Track Classification: ASIC