Production Test Rig for the ATLAS Level-1 Calorimeter Trigger Digital Processors

J.R.A. Booth, D.G. Charlton, C.J. Curtis, P.J.W. Faulkner, S. Hillier, G. Mahout*, R.J. Staley, J.P. Thomas, D. Typaldos, P.M. Watkins, A. Watson, E.E. Woerhling

School of Physics and Astronomy, University of Birmingham, Birmingham B15 2TT, UK

R. Achenbach, V. Andrei, F. Föhlisch, C. Gewiniger, P. Hanke, E-E. Kluge, K. Mahboubi, K. Meier, F. Rühr, K. Schmitt, H.C. Schultz-Coulon, P. Weber

Kirchhoff-Institut für Physik, University of Heidelberg, D-69120 Heidelberg, Germany

B. Bauss, S. Rieke, U. Schäfer, R. Stamen, S. Tapprogge, T. Trefzger

Institut für Physik, Universität Mainz, D-55099 Mainz, Germany

E. Eisenhandler, M. Landon

Physics Department, Queen Mary, University of London, London E1 4NS, UK

B.M. Barnett, I.P. Brawn, A.O. Davis, J. Edwards, C. N. P. Gee, A.R. Gillman, V.J.O. Perera, W.Qian, D.P.C Sankey

CCLRC Rutherford Appleton Laboratory, Chilton, Oxon OX11 0QX, UK

C. Bohm, S. Hellman, A. Hidvégi, S. Silverstein

Fysikum, Stockholm University, SE 106 91 Stockholm, Sweden

Abstract

The Level-1 Calorimeter Trigger is a digital pipelined system, reducing the 40 MHz bunch-crossing rate down to 75 kHz. It consists of a Preprocessor , a Cluster Processor (CP), and a Jet/Energy-sum Processor (JEP). The CP and JEP receive digitised trigger-tower data from the Preprocessor and produce electron/photon, tau, and jet trigger multiplicities, total and missing transverse energies, and Region-of-Interest (RoI) information. Data are read out to the data acquisition (DAQ) system to monitor the trigger by using readout driver modules (ROD). A dedicated backplane has been designed to cope with the demanding requirements of the system. A number of pre-production boards were manufactured in order to fully populate a crate and test the robustness of the design on a large scale. Dedicated test modules to emulate digitised calorimeter signals have been used. All modules, cables and backplanes on test are final versions for use at the LHC. This test rig represents up to one third of the Level-1 digital processor system. Real-time data between modules were processed and time-slice readout data was transferred to the ROD at a trigger rate up to 100 kHz. Intensive testing consisted of checking the readout data by comparing to hardware simulations of the trigger. Domains of validity of the boards were also measured and dedicated stressful data patterns were used to check the reliability of the system. Tests results have been successful and the Level-1 calorimeter trigger system is proceeding to full production.

Summary

The ATLAS Level-1 Calorimeter Trigger system reduces the LHC bunch-crossing rate of 40 MHz down to a rate of 75 kHz. About 300 Gbytes/s of input data are processed and events are selected within a fixed time of 2µs. The algorithms of selection are FPGA-based to add flexibility to the system. Data are digitised and pipelined by using three

* Corresponding author: gm@hep.ph.bham.ac.uk

subsystems, namely the Preprocessor, electron/photon and tau/hadron Cluster Processor (CP), and Jet/Energy-sum Processor (JEP). The CP and JEP receive their digitised calorimeter trigger-tower data from the PreProcessor, and provide trigger multiplicity information to the Central Trigger Processor via Common Merger Modules (CMM). Using Readout Driver (ROD) modules, the CP and JEP will also provide Region-of-Interest (RoI) information for the Level-2 Trigger, and intermediate results to the data acquisition (DAQ) system for monitoring and diagnostic purposes.

The CP and JEP system receive their data through backplane connections. A custom backplane has been designed in order to cope with the high connectivity demands of the system and to route data between boards in order to accommodate the trigger decision algorithms. The backplane also needs an adaptor for a VME CPU board and an additional module to broadcast the 40 MHz TTC encoded information to the modules in the crate.

The CPM and JEM have common design features. Both received digitised data in LVDS format at a rate of 480 MBaud. Single-ended serialised data between boards across the backplane is processed up to a speed of 160 MHz in case of the CPM. The CMM gathers information through the backplane, but also between crates, and transfers the trigger information to the overall Level-1 Central Trigger Processor.

All Calorimeter Trigger modules transmit their readout data using G-link transceivers. These are connected to RODs, capable of processing up to 18 modules individually.

All trigger modules, with the exception of the VME CPU, are custom designs. Although every module had been developed and tested and seemed ready for production, it was important to validate the final versions of the different modules in harsh conditions. The production was therefore divided in two phases: a first batch was manufactured with an adequate number of pre-production boards to perform a full-crate test, and only after seeing the results would the remainder of the modules be produced. Up to 14 CPMs and 16 JEMs have been built, representing nearly one third of the final digital part of the trigger system. The cables delivering the digitised signals were used, together with the final custom backplane. The source of data was provided by specially designed boards that emulate the total input of one CPM or JEM, corresponding to around 70 Gbytes/s of transferred data when the crate was fully configured. All readout information was fed to a ROD.

Previous tests had been run using the ATLAS online software. It was therefore easily expandable to a system of such a scale by extending the database. With a full crate in operation, bit-error rate measurements or parity checks were performed over long-term runs. A simulation framework was already available, and individual readout data were compared against the simulation to verify the correct behaviour of the different algorithms. Domains of validity of the data were measured by shifting the 40 MHz clock over its period. To detect any timing misalignment, Level-1 pre-flagged events were sent to a ROD. Trigger rates up to 100 kHz were investigated. Stressful data patterns were created in order to test the reliability of the system with an ATLAS occupancy rate greater than 10 %. The system was also monitored using the PVSS tools to check for current consumption and temperature hot spots inside the crate.

The results of the tests were successful and the ATLAS level-1 calorimeter system is now proceeding to full production.