Initial Experience with the ZEUS Central Tracking Detector Second Level Trigger and Data Acquisition System

J. Butterworth, A. Byrne, R. Devenish, D. Gingrich, P. Hallam-Baker, I. McArthur, J. Nash, N. Roocroft & S. Topp-Jørgensen

Department of Particle & Nuclear Physics, University of Oxford, Keble Road, Oxford, OX1 3RH, UK

The ZEUS central tracking detector second level trigger and data acquisition system are implemented in a network of approximately 120 INMOS transputers. Data suppression, triggering and readout in 34 crates of electronics are performed concurrently by exploiting data parallelism and pipeline processing in the network architecture. The system is data driven at the ZEUS first level trigger rate of 1 kHz and must provide second level trigger information after a mean processing time of 5 ms. This paper describes the initial performance of the system and the experience gained from the first beam collision periods at HERA.

Introduction

The electron-proton collider HERA has been providing collisions for the experiments since June of 1992. As the number of accelerated electron and proton bunches increase, the brief bunch-crossing interval (design value of 96 ns) will put stringent requirements on the trigger and data acquisition (DAQ) systems. Trigger systems must reduce the beam-gas background interaction rate of about 10^5 Hz to a few Hertz, at which the deep inelastic interactions of interest are expected to occur at HERA. The trigger and DAQ systems must select and process a large amount of data to produce the 100 kbyte per event that can be written to disk on the DESY-IBM at these rates.

A three level trigger system has been built for the ZEUS detector at HERA. The first two levels are component based while the third level is a farm of Silicon Graphics 35S machines running full reconstruction code. The design goal of the first level trigger is an accept rate of 1 kHz. The task of the second level trigger (SLT) is to further reduce the rate by a factor of 10 (to 100 Hz). The necessary reduction by the trigger system at the first and second levels can only be achieved by using pipelined-parallel processing.

Determining the position of the primary event vertex within the ZEUS experiment will be crucial for rejecting the non-electron-proton interactions and is one of the major functions of the central tracking detector (CTD) [1]. The ZEUS CTD is provided with two separate readout systems. Accurate trajectories of charge particles are measured in the plane perpendicular to the beam by collecting ionization on the sense wires in the chamber and digitizing these signals by flash analogue-to-digital converter (FADC) modules. Digital signal processors are subsequently used to zero-suppress and parameterize this data. Less accurate position information is obtained in the direction along the beam by digitizing the time difference between the arrival of pulses at the two ends of some of the sense wires which are parallel to the beam. The latter system (z-system) provides the input to the CTD first level trigger, while data from both systems and correlations between them are available to the CTD-SLT. Details of the CTD electronics can be found in References 2 and 3.

CTD Second Level Trigger and DAQ System

The CTD-SLT and DAQ system runs on a network of INMOS transputers and is coded in the occam programming language [4]. The network and algorithm have been designed to exploit the natural parallelism inherent in the CTD geometry. Transputer links provide the means of data transfer and communication within the network, and with the ZEUS experiment. The trigger transputers plus transputers needed for readout and monitoring of the CTD comprise an array of more than 120 inter-connecting processors (several hundred for all of ZEUS).

The software system as a whole requires many hundreds of inter-communicating processes to be placed on the transputer array. To reduce the effort required to develop and maintain the code, tools have been developed to automatically insert code fragments into the programme bodies and to simultaneously generate the required communication channels and network configuration description [5].

The system has been extensively studied using Monte Carlo simulated data. Simulated background and physics processes have been used to test the rejection power and efficiency of the algorithms. In addition, a package for the simulation of asynchronous parallel systems has been written and used to predict the network dead-time and bandwidth [6].

Experience and Initial Performance

Prior to the first collisions at HERA it was realised that some hardware components of the CTD first level trigger and FADC system would not be ready in time. Hence the decision was made to modify the SLT algorithm and DAQ network to readout and trigger using information from the z-system only. This temporary configuration was not anticipated in the design but within a few weeks the transputer network and SLT algorithm were modified to work with the z-system only. The trigger algorithm is now backwards compatible with the original design and the transputer array allows crates of FADC electronics to be added as they become available with minimal disruption to the system.

Cosmic ray test runs provided the first experience with integrating the CTD-SLT and DAQ network into the ZEUS-DAQ and run control systems. A single-crate trigger and readout system with all the necessary global processors for the final network were coded during this period. During the commissioning of HERA for the first electron-proton collisions, the CTD-DAQ system was expanded from one to 12 z-crates as further hardware became available - due to the lack of CTD first level trigger processor boards only 12 crates, rather than 16, were required to completely readout the z-channels of the CTD. The modifications to the software to add additional crates required no further code to be written. The number of crates in the system was specified and the required communication channels and configuration code for the network were automatically generated.

The current CTD-DAQ and SLT system is distributed over 12 crates of electronics

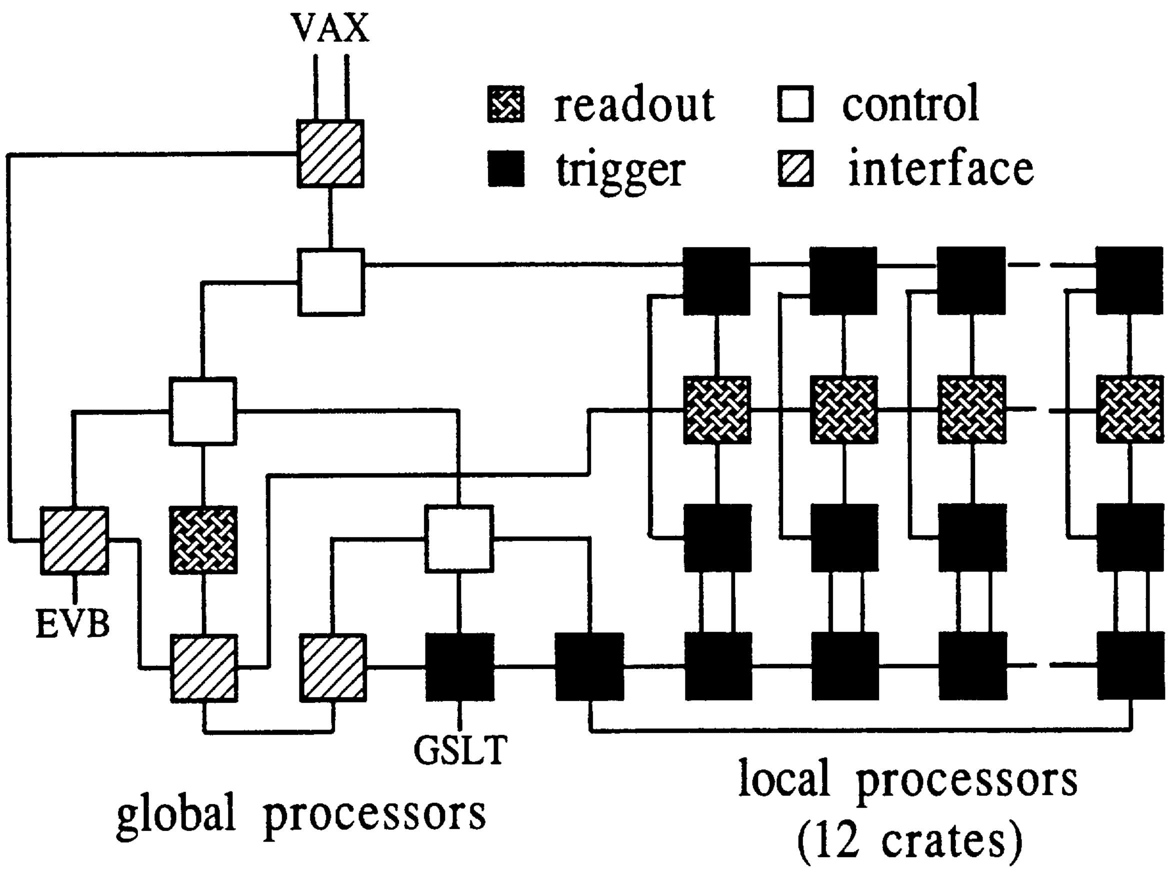

Figure 1: The CTD transputer network used in the first beam collision period at HERA.

with a further two crates providing the global functions of the network. Figure 1 shows the transputer array used in the first beam collision period at HERA. There are 38 processors allocated to the second level trigger and 13 processors to readout. Three transputers handle control and multiplexing functions, while a further four transputers are required to provide extra links in the network. In total, the system comprises 58 processors of which approximately half are T425 transputers and half T800 TRAM's. All transputers in the system have 1 Mbyte of external memory and are mounted on custom-built readout controller boards.

Since the number of bunches currently accelerated by HERA is less than the design number and the full ZEUS trigger system in not yet operational, the output rate of the global first level trigger is limited to about 10 Hz. Our transputer array has no problem with this rate and measurements indicate that the current network should be capable of an input rate of approximately 500 Hz with little dead-time. We anticipate achieving the 1 kHz design rate when the need arises.

Because of the absence of the full ZEUS first level trigger system the cosmic ray background rate was high. The first job of the CTD-SLT was to reduce this rate by a factor of four by exploiting information from track segments. A further reduction of about a factor of 80 is anticipated if full use is made of the CTD-SLT track information.

The CTD-SLT is monitored online by a set of standard ZEUS histograms and detailed offline histograms are periodically examined. Software has been written which can create test input data for the CTD-SLT either from the previously recorded raw data or from a Monte Carlo simulation. This playback facility allows modifications of the system to be tested using the network *in situ* on real data. In addition, software exists to compare the results of the CTD-SLT with either the offline reconstruction code or with a detailed simulation. Agreement between the simulation and the real system is exact for calculations involving integer arithmetic, while calculations involving real arithmetic agree very well; the number of found tracks in an event agree to better than 99.3%. Since the simulation has been used for a number of years to help design the system, we feel confident that the CTD-SLT is performing as anticipated.

Summary

We have designed and built a second level trigger and data acquisition system for the ZEUS central tracking detector that uses parallel processing and runs asynchronously on a network of transputers. The system has been tested using data from the first two collision periods at the electron-proton collider HERA. The performance is encouraging and we anticipate reaching our design goals when the full system is operational.

Acknowledgements

Thanks to T.J. Llewellyn for writing the CTD run control system and T. Khatri for providing the initial z-readout code.

References

[1] ZEUS-UK Collab.: C.B. Brooks *et al.*, "Development of the ZEUS Central Tracking Detector", Nucl. Inst. & Meth. **A283** (1989) 477-483.

[2] D.G. Cussans *et al.*, "The Design, Status and Performance of the ZEUS Central Tracking Detector Electronics", Nucl. Inst. & Meth. **A315** (1992) 397-403.

[3] B. Foster *et al.*, "The Performance of the ZEUS Central Tracking Detector z-by-Timing Electronics in a Transputer Based Data Acquisition System", Third International Conference on Advanced Technology and Particle Physics, Como Italy, 22-26 June 1992, to be published in Nucl. Inst. & Meth.; University of Oxford Preprint, OUNP-92-14.

[4] R.C.E. Devenish *et al.*, "ZEUS Central Tracking Detector Second Level Trigger and Readout Architectures", AIP Con. Proc. **209** (1990) 155-162.

[5] D.M. Gingrich, P.M. Hallam-Baker & I.C. McArthur, "Software Tools for Transputer Networks", Second International Workshop on Software Engineering, Artificial Intelligence and Expert Systems for High Energy and Nuclear Physics, L'Agelonde France, 13-18 January 1992, to be published by World Scientific Pub.; University of Oxford Preprint, OUNP-92-02.

[6] P. Hallam-Baker, D. Gingrich & I. McArthur, "A Package for the Simulation of Asynchronous Parallel Systems", AIP Con. Proc. **209** (1990) 378-385.