FRONT-END I/O OF THE ATLAS DETECTOR CONTROL SYSTEM

H.J. Burckhart and B. Hallgren
CERN, Geneva, Switzerland

Abstract

The importance of using a powerful Detector Control System (DCS) has much increased with the size and complexity of High-Energy Physics detectors. The generation of detectors for the LHC experiments puts further requirements onto the front-end I/O system due to the inaccessibility of the equipment and the hostile environment concerning radiation and magnetic field. Novel techniques such as fieldbuses for distributed input/output and Programmable Logic Controllers (PLC) for closed loop control have to be employed. These represent the layer closest to the detector of a hierarchically organized multi-layer DCS. After an introduction of the organization of the ATLAS detector and of the concept and the architecture of DCS the paper will concentrate on the usage of fieldbuses as front-end I/O bus with special emphasis on industrial standards of hardware and software.

1 ATLAS ENVIRONMENT

ATLAS [1] is a general-purpose detector for use at the Large Hadron Collider (LHC) at CERN, which will start operation in 2005. From the point of view of physics, the detector is composed of 3 components: the Inner Tracker with particle identification, the calorimeter and a muon detection system. The latter consists of tracking chambers placed in a magnetic field created by a complex air-core super-conducting spectrometer magnet. The outer dimensions of the barrel-shaped detector are 46 meters in length and 22 meters in diameter.

From the point of view of controls the detector is composed of largely independent units, organized in a tree-like structure of many levels. The highest level consists of the six subdetectors, which use different particle detection techniques: the silicon pixel detector, the silicon strip detector, the Transition Radiation Tracker, the calorimeter using liquid argon, the calorimeter based on iron and scintillator tiles and finally the muon chamber system. The control of the magnets and of the common infrastructure of the experiment like electronic crates, racks and cooling is also placed at this level. Each subdetector is subdivided in further unit as Fig 1 schematically shows. This subdivision varies from subdetector to subdetector and is chosen for different reasons like functions, operations, and geometry or just for organizational reasons, when different groups of the ATLAS collaboration build different parts of the same subdetector. These units will be constructed at different places around the world and need to be controlled in a stand-alone way first. Once they are installed, they will be operated integrated as one detector. It is important for the design of the controls system, that the main information flow, both data and commands, is normally only vertically. Horizontal interaction takes place only in exceptional cases and it is therefore acceptable to go one level up and then down again. Concerning controls the detector can hence be modeled as hierarchical "objects".

2 STRUCTURE OF DCS

The DCS is also organized in layers as shown in Fig. 2. The surface control room and the underground electronics rooms, which are also accessible during operation, house workstations for operation and servers for functions like

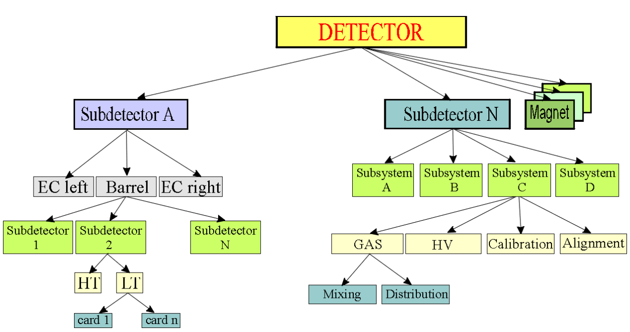

Fig. 1 Hierarchical Organization of the detector

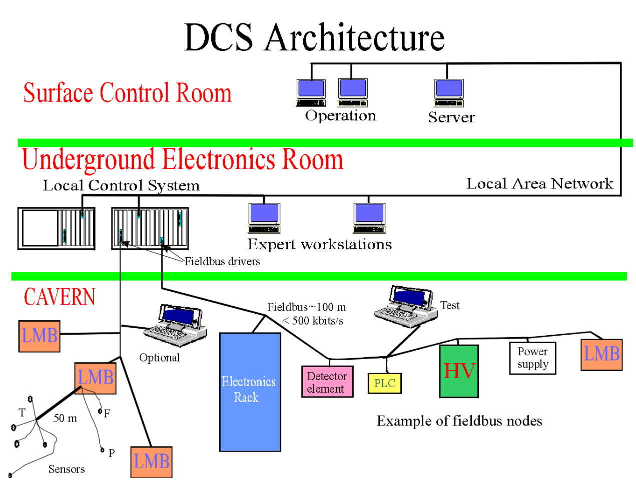

Fig. 2 Layout of DCS

data base, communication with external systems etc. Local Control Stations (LCS) supervise in a largely autonomous way a well defined part of the experiment as a gas system, a complex high voltage unit or a topologically defined part of a subdetector e.g. a whole endcap. We intend to use a commercial Supervisory Control And Data Acquisition system (SCADA) for the upper part of DCS.

The lower part of DCS consists of the front-end I/O system, which is located in the experimental cavern, and is not accessible during operation. This part reads out individual sensors and actuators but also supervises devices like power supplies or gas instrumentation and more complex equipment like alignment systems. The interconnection between both parts of DCS is done either via standardized protocols over a local area network, or by using a fieldbus.

3 FRONT-END I/O SYSTEM

The front-end I/O system has to fulfill special requirements. We consider here only the situation outside of the calorimeter, which absorbs fully electrons and photons. The radiation left consists of mainly of neutrons, about 10^{11} particles/cm^2 over 10 years of operation. Two effects harmful to the electronics have to be taken into account. The first is a gradual damage of the lattice of semiconductors, which results in a degradation of their characteristics like loss of gain or increase of currents. The second effect consists of the so-called Single Event Upset (SEU), where a bit in a memory cell changes its content.

Another requirement is the operation of the controls electronics in a magnetic field of up to 500 Gauss, created by the toroid magnets. And finally, the I/O points are distributed over the whole volume of the detectors with distances up to 100 meters.

3.1 Components of the I/O system

The standard approach adopted by ATLAS is to place I/O concentrators with limited local processing capabilities in the cavern and transfer the data to the LCS for further processing. According to the complexity of the task and the nature of the equipment, different solution will be employed.

3.1.1 Stand-alone systems

These are systems, which are largely autonomous and just accept commands from DCS and give results back. Examples are commercial instruments like a gas chromatograph. Other stand-alone systems will be custom built out of commercial components. For example the muon alignment system is based on optical images, from which dedicated processors will calculate alignment constants and send the results to DCS. In the case of a very high number of the same type of channels in the range of several ten thousands, a VME based system with a high level of multiplexing and dedicated data reduction is foreseen. Normally only the summaries and perhaps a few selected channels will be transmitted to the SCADA system for monitoring. However the possibility is needed to dynamically select other channels and in case of problems treat them also in the SCADA. Also time-critical systems, which have to react on the millisecond level like fast radiation monitoring in the detector, will be implemented as stand-alone systems.

3.1.2 Programmable Logic Controllers (PLC)

For applications where reliability is very important and where the controls algorithms do normally not change, PLCs are very suited. The program consists essentially of one big loop, which reads all inputs and after data processing sets the outputs. Closed loop control is a typical application.

3.1.3 Fieldbus nodes

Using a fieldbus will be the standard way to connect I/O systems to the LCS. There exists a wide variety of fieldbuses on the commercial market with different characteristics. We have chosen CANbus and the CANopen protocol because it is robust, open, low-cost and easy to use. Also the support by industry is very good, both on the level of chips and full products.

Different types of fieldbus nodes will be used. In some commercial equipment like electronic crates or power supplies, fieldbus nodes are embedded for monitoring and control. Purpose-built nodes, using commercial chip sets, are part of some of the electronics of ATLAS detector elements like the muon chambers. A general purpose I/O system based on the CAN fieldbus has been developed and is summarized in the next chapter.

Fieldbus nodes can be programmed and the range of functions possible is very wide. The minimum is to read/write sensors/actuator. The data can also be converted into physical units and analyzed in a simple way like averaging or detecting trends. Buffers can hold history of data. There is also the possibility to compare to limits and detect alarms or trigger actions. Even advanced functions like closed loop control or modeling the state of a device can be implemented in a fieldbus node. The level of data processing to be done in the fieldbus node depends on the stability of the algorithms and the capacity of processor and memory. It has also to be kept in mind, that SEU can corrupt programs. It is important to be able to detect this on-line and to reload the program.

3.2 General purpose I/O system

Normal sensors and actuator can be supervised with a limited set of functions. As this is a standard application across all subdetectors, a general purpose I/O system called Local Monitor Box (LMB) has been developed. It is based on CANbus read out and the CANopen software protocol. In the following only its main features are summarized as it is described in detail in another contribution to this conference [2].

In the design of the LMB care has been taken to reach the required level of radiation tolerance. Only applications outside of the calorimeter are considered. The electronics of the Inner Tracker has to stand a much higher level of radiation and will hence use special radiation hard technology. The LMB however should be implemented with standard Components Off The Shelf (COTS). Its performance is designed to be substantially higher then the requirements of the applications and the electronics components are used well below their specification limits in order to allow for degradation due to radiation. The radiation tolerance of the LMB has been verified by operation in a radiation environment. The system has been also used successfully in a magnetic field of 1 kGauss.

The LMB consists of 3 main components: the CAN controller module, front-end I/O modules and signal adaptation modules as shown in figure 3. The controller module contains two micro controllers in order to allow downloading and checking of the programs via the CANbus. The first I/O module, which has been built, is an ADC with 16-bit resolution and 7 bit dynamic range. A multiplexer allows connecting up to 64 channel to it. Signal adaptation boards have been built for temperature sensors with 2- and 4-wire connections, and for voltage and current measurements. Some applications need to use the same sensor for both measurement and creating an interlock signal. A typical example is to interlock a power supply in case of an over-temperature. For this purpose an interlock box has been developed, which is connected in parallel to the sensor and does not interfere with the LMB.

Measurements have been performed with several subdetector prototypes. The temperature of the liquid argon calorimeter at 90 K has been measured with a resolution of 0.8 mK and an absolute precision of 3 mK. The long-term stability over one month was found to be 50 ppm. These numbers show that the expected performances have been reached and it has also been proven, that the digital read out over the CANbus does not influence the highly sensitive read out electronics of the detector. Further I/O modules like digital I/O and DAC are in preparation. Dedicated modules like bus converters to local on-board busses as I2C or JTAG are also easily possible, as the micro controllers can be programmed by the user.

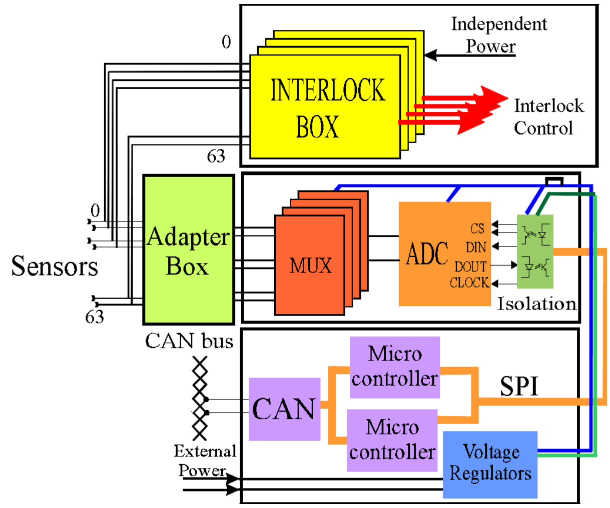

Fig. 3 Block diagram of the LMB

4 CONCLUSIONS

The ATLAS DCS is composed of two parts, a SCADA system and a front-end I/O system and is organized in several hierarchical levels. This allows easy mapping of the tree-like structured detector entities onto controls units. The connection between the SCADA and the I/O system is largely based on the commercial CAN fieldbus, which reads both commercial and purpose-built nodes. A general-purpose CANbus based I/O system has been developed, which will be used for many subdetector applications. Its performances and radiation hardness has been proven.

REFERENCES

[1] ATLAS Technical Proposal, CERN/LHCC/94-43, 15.December 1994

[2] B.Hallgren et al., A lowcost I/O concentrator using the CAN fieldbus, contribution to this conference