13 Detector control

The ALICE Detector Control System (DCS) is designed for monitoring and control of correct operational conditions of the ALICE sub-detectors. As this task also involves safety aspects, the hardware links used are independent of the DAQ. The ALICE DCS project is presented in Ref. [1]. The ALICE DCS system is described in Ref [2] and will be described in detail in a future document. Its functionalities include (see also Ref. [3]):

- starting or shutting off a detector, or components of a detector, in a controlled way;
- monitoring of characteristics (analog and/or status values) which are necessary for detector operation and/or the physics data analysis;
- reporting of alarm conditions and initiation of the appropriate response;
- logging and archiving of characteristics, alarms and operator interactions;
- retrieving archived data for trend displays or detector analysis;

In addition, interactions are required with a number of external systems like the area safety system, gas system, cooling and ventilation system, electricity mains supply, LHC, and magnets. However, certain of these systems will only provide informative links to the DCS:

- during normal physics data-taking the DCS will control starting and operation of all the ALICE sub-detectors. For this purpose standard operator commands will be available. Malfunctioning will be signalled to the detector-dedicated control station via centralized alarms.
- during installation and/or maintenance periods it will be necessary to run different detectors, or partitions of them, separately but simultaneously. In this case interference among detectors or between them and external services must be screened.

To satisfy the above requirements the DCS architecture will have two essential features –scalability and modularity– and will be based on distributed intelligence. The detector control system will be designed and organized in layers, corresponding to different levels of visibility and access rights. The higher levels will have a more global view, and will only be allowed to make a limited set of macroscopic actions. On the other end, lower layers will have access to more detailed information and control. At the highest level of the experiment a Supervisory Control layer will provide the communications among the main ALICE subsystems such as the Data Acquisition Control (DAQC), the Trigger Control (TRC) and the DCS. The DCS will be accessed through the Supervisory Control layer. No peer-to-peer connection between DCS and DAQ is envisaged. The Supervisory Control will have the following features:

- provide a global view of the whole experiment to the operator.
- allow the control of the experiment through commands to the DCS, the DAQC and the TRC. It will be capable of generating the sequence of operations in order to bring the experiment to a given working condition. However, detailed actions will be the responsibility of the subsystems.
- collect and dispatch all the communications between the subsystems.
- monitor the operation of the subsystems, generate alarms, and provide the interlock logic where necessary.

- allow the dynamic splitting of the detector into independent partitions and the possibility of concurrent data-taking from the partitions.

Hardware protection of TRD components will be implemented wherever possible. This is the case, for example, for the ramp-down of sense wire high voltages in the presence of sustained over-currents.

13.1 Hardware

Within ALICE we intend to develop a DCS system which is as standardized and identical across detector boundaries as technically feasible. Consequently, similar to the general ALICE DCS, the hardware structure of the TRD DCS will be structured in three layers.

- **Field layer.** This is the layer of field instrumentation such as sensor heads, actuators, etc. The field instrumentation has to comply with the requirements of the detector hardware. The interfaces to the control equipment will follow well-established electrical standards like 0–10 V for voltage interfaces or 4–20 mA for current-loop interfaces. The signals to be monitored for the TRD detector are listed in Table 13.1.

  Each front end Multi Chip Module (MCM) which acquires and processes signals from 18 pads also implements measurements of chip temperature, power voltages and currents and power on/off control of the readout-related section of MCM.

  Sensors of gas temperature, LV connector and cable temperature, LV regulator current and voltage and humidity will be read out by a dedicated DCS ADC located on the MCM.

  For monitoring of the detector status outside the running period we foresee operation of the MCM in standby mode, where only the part essential for DCS (multiplexed ADC, duplex synchronous daisy-chained serial link and DCS control) will be powered (See architecture of the DCS communication in Fig. 13.1).

  Independent power distribution will be used only for key components of the system such as controllers, sensors and actuators of the cooling and gas system and hubs distributing the information between them and workstations on control and supervisory layers.

  In the process controllers the CAN interface will be implemented as backup option.

- **Control layer.** This corresponds to multipurpose-control computer equipment of the Programmable Logic Controller (PLC) type, in compliance with the relevant recommendation [4]. However, wherever convenient in the case of a large number of field-instrumentation channels to be controlled, VME-based controllers may be used. This hardware layer also includes self-contained intelligent instruments like high- and low-voltage power supplies.

  For the part of the DCS system located on the detector we currently investigate Ethernet as a detector control field bus. Ethernet is rather rugged and AC coupled. In tree configuration and using twisted pair distributions it permits 100 Mbit/s throughput over long distances. Failure on one of the branch nodes does not disturb the rest of the network communication. This solution is two orders of magnitude faster than the top speed of CAN Bus over short distances. For the Ethernet solution to be viable, it has to be ensured that the implementation of all links under any operational condition is provided by fully standard, well supported industrial solutions.

  The currently very rapid development of single-board CPUs and programmable gate arrays (FPGA) running Linux permits the use of miniature controllers which allow implementation of the Ethernet interface and any other controls functionality together with the CPU. The only additional external components required are an Ethernet transceiver (small SMT chip), one flash ROM, and a single chip DRAM. Typical configurations include 8 MB flash ROM and 64 MB DRAM.

  Concerning the development of controllers we plan three phases:

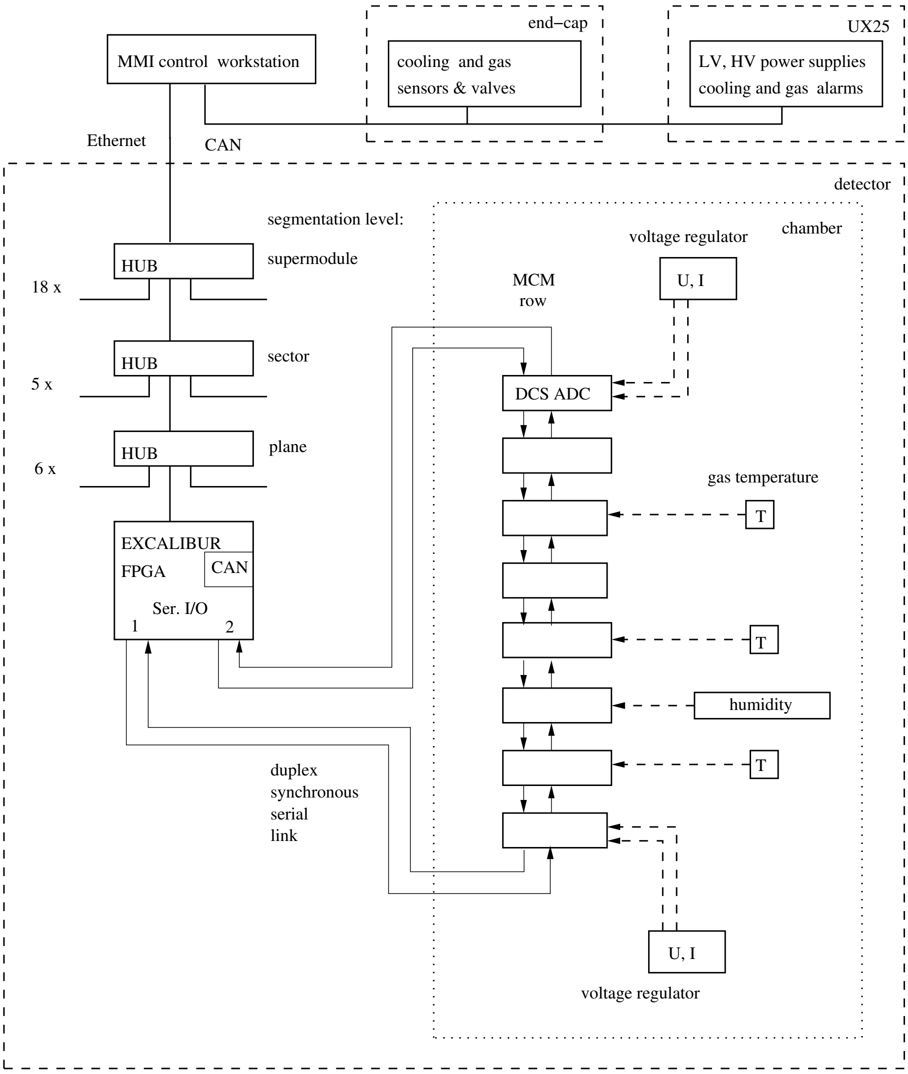

Figure 13.1: Architecture of the DCS communication.

– a miniature single-board computer based on MC68EZ328 DragonBall microcontroller is currently used for evaluation tests . It will be used also for tests of compatibility of Ethernet and the ALICE environment (operation in 0.5 T magnetic field) this year. This board supports only the 10 Mbit Ethernet.

– in the second phase, a controller based on the ALTERA 20K200 FPGA chip will be developed. This controller will implement a synthesized UC (NIOS processor with a 40 MIPS 16-bit CPU) together with Ethernet and an optional CAN interface.

– finally, at the beginning of next year, the Altera Excalibur chip (also from ALTERA 20k FPGA family but with a hard processor core ARM or MIPS both able to run beyond 200 MHz) will be available also with Ethernet on the FPGA as IP core with no need of external chips. Both FPGA Ethernet implementations run 100 Mbit/s. In the long run ALTERA will probably not be the only supplier of such devices. Other possibilities might include Xilinx, appropriate market surveys are underway.

- **Supervisory layer.** The equipment in this layer consists of general-purpose workstations which will be linked to the control layer through TCP/IP. The workstations will provide the Man-Machine Interface (MMI) to the DCS and will behave as server stations for detector monitoring and data logging, or as client stations for detector control. At the level of general supervisory control, the workstations will be dedicated to the management of configuration data for all the detectors and equipment, partitioning, alarms, logging and archiving, and data communication.

13.2 Communication

The data transmission links can be classified in layers equivalent to the hardware architecture. At the field-instrumentation level, point-to-point links for voltage or current signals will be the general case.

Most analog sensors placed on the detector will be read by the DCS ADC located on the MCM. Voltage for the MCM is regulated on-board and output voltage and load current of the regulator will also be read by the DCS ADC on the MCM .

Devices and sensors placed on the detector end-cap and in UX25 will be read out using one of the recommended field buses.

For communication between the DCS controller and the MCM we foresee a fast duplex synchronous serial link running at $\approx$100 Mbit/s. This link will be used for downloading the MCM CPU software, setup, DCS control, and preamplifier pulser test. A serial link will be connected on both sides of the MCM chain to the controller, so that a failure of one MCM will not cut the communication to the rest of chain.

This configuration does not change the hardware architecture since the bus system will be seen as an extension of the controller station.

13.3 Software

The controller-level software, which will reside in the control computers that are directly linked to the process, will be configured individually for each sub-detector.

For controllers based on the proposed FPGA, Linux (UCLinux) kernels are available which do not implement a man-machine-interface (MMI) but otherwise are complete Linux systems allowing, for example, to NFS mount external discs, run http , secure shell or telnet.

Software development becomes very simple, the front-end mounts the host's disk, the software is cross compiled into the mounted /bin partition and the program under test is started via remote shell.

For development and maintenance of the detectors each group will also configure a personalized MMI. This software will be based on the same product(s) as for the ALICE DCS system and will therefore allow integration into the overall system during operation of the experiment and will grant separate access and control of each subsystem during other periods.

It is planned that the driver software for the controller stations to interface the field instrumentation to the ALICE DCS architecture will be based on the OPC [5] standard. This means that hardware and applications from different manufacturers can be easily connected. OPC is currently being evaluated in the context of the CERN JCOP project. It is based on the Microsoft technology DCOM (Distributed Component Object Model) and provides a standardized access method and unified interface between the control layer and a SCADA (Supervisory Control And Data Acquisition) system on the supervisory layer. The OPC interface standard is defined and developed by the OPC Foundation which includes the major companies in the automation sector (Siemens, Fisher-Rosemount, National Instruments, Rockwell Software, et al.). A wide range of OPC servers and applications are already available and additional companies have announced their adherence to this standard.

13.4 Safety and quality management

13.4.1 Mechanical

All mechanical components will be designed and built according to the quality assurance standard ISO 9001 or an equivalent national standard.

Although the TRD detector will be operated at a pressure of 1 mbar above atmospheric pressure, the detectors are designed for a maximum over-pressure of 2 mbar.

13.4.2 Gas

In addition to adherence to mechanical tolerances, the fabrication, finishing, and choice of materials must ensure an adequate gas purity in order to run the detector with the desired performance and within operational cost. Since the TRD detectors are filled with a Xe,CO_2 mixture, excessive leaks lead to intolerable gas flows and the need for the injection of fresh gas. Avoiding such leaks is especially important in view of the cost of Xe gas. It is therefore foreseen that detailed leak tests will be performed at the detector construction sites.

The gases used in the TRD are non-flammable. As far as the detectors are concerned, redundant and stand-alone safety mechanisms have been implemented in order to protect the TRD from under- or over-pressures.

13.5 Radiation protection

The two main mechanisms that may induce radioactivity in the TRD are low-energy neutron activation and inelastic hadronic interactions at high energy. The maximum neutron fluences over a period of ten years at the mean radius of the TRD are below $1.0 \times 10^{11}/\text{cm}^2$, respectively. Scaling from the equivalent dose rates induced by the high-luminosity pp interaction regions [7] to those of the ALICE experimental conditions (approximately a factor of 100 lower), we do not expect any radiation hazards to be caused by the accumulation of radionuclides in the TRD.

13.6 Electrical system protection

13.6.1 High voltage for readout chambers

The readout chambers require an operating voltage of less than 1700 V. In total, 540 supply lines are needed. In addition, there are 540 supply lines for the HV to the field cage of each chamber. Here the operating voltage will be less than 3000 V. The installation is based on standard coaxial high-voltage cables rated for at least 3 kV, together with standard high-voltage connectors.

Standard, remotely-controlled power supplies with voltage and current monitoring will be used. If an over-current is detected, the corresponding voltage will be ramped down at a preset rate. Operation of the HV system will be interlocked in case of a cooling water leak. No parts of the readout chambers under high voltage are accessible once the chambers have been installed.

13.6.2 Low voltage

The front-end electronics of the TRD is a typical low-voltage high-current system ($\approx$ 20 kA in total), which may run the risk of fire in case of uncontrolled currents. To avoid any danger to the TRD and its readout system, the following strategy has been adopted.

The power supplies themselves are ground-free. The ground reference is obtained only at the detector side. This avoids any accidental parasitic currents in the conducting paths (not adapted to such large currents) flowing back to the power supply if one of the ground lines is broken.

Powering of the system will be monitored by the DCS. Each MCM provides a measurement of all the incoming voltages and currents. If there is a voltage drop or over-current, the system can be powered down on a time-scale of milliseconds. By monitoring also the temperature of each MCM, the DCS can react to temperature excursions, and shut off the relevant section of the system.

Furthermore, the design of the MCM and their connections to the ground of the readout chamber is such that the copper cross-section is sufficiently large to accommodate high current densities (see Section 9.1.2). This could be required if the ground return line is accidentally connected to the general ground, which would lead to a parasitic current through the TRD support structure.

Table 13.1: Main parameters of the Detector Control System for the TRD.

Systems/sub-systems	Location	Controlled parameters	Number	Link type	Parameters	Control
FEE cooling	end-cap	inlet and outlet liquid-coolant temperature	216	analog	temperature	Read/Write
	end-cap	inlet and outlet liquid-coolant pressure	36	analog	pressure	R
	end-cap	liquid-coolant valve control	18	binary	voltage	R/W
	detector	gas temperature	4860	analog	temperature	R
	UX25	temperature threshold for cooling alarm	2	analog	voltage	R/W
	UX25	pressure threshold for cooling alarm	2	analog	voltage	R/W
	detector	humidity sensor for water leak alarm	1620	analog	humidity	R
	PX24	safety switch	1	binary	voltage	on/off
FEE control	detector	FEE temperature	64224	bus	temperature	R
	detector	FEE voltage regulation	64224	bus	current	R/W
	detector	interface (status, exceptions, pedestals, events)	64224	bus	complex	R/W
	detector	MCM on/standby	64224	bus	bit pattern	on/standby
FEE low voltage	UX25	FEE power supply	108	serial	current	R/W
	UX25	FEE power supply temperature	108	analog	temperature	R
	UX25	FEE power supply status/enable word	108	serial	bit pattern	R/W
	detector	FEE voltage regulation	16056	bus	current/voltage	R/W
	end-cap	connector and cable temperature	648	analog	temperature	R
	PX24	safety switch	1	binary	voltage	on/off

Table 13.2: Main parameters of the Detector Control System for the TRD, continued.

Systems/sub-systems	Location	Controlled parameters	Number	Link type	Parameters	Control
Drift HV	UX25	HV supply on/off	540	serial	voltage	R/W
	UX25	HV setttings and readings	540	serial	complex	R/W
	UX25	safety switch	1	binary	voltage	on/off
Readout chambers	PX24	HV supply on/off	540	serial	voltage	R/W
	PX24	HV settings and readings	540	serial	complex	R/W
	PX24	safety switch	1	serial	voltage	on/off
Gas system	PX24	primary inlet and outlet gas temperature	2	analog	temperature	R
	PX24	primary inlet and outlet pressure	4	analog	pressure	R
	PX24	primary inlet and outlet gas flow	2	analog	flow	R
	PX24	regulation	5	serial	complex	R
	PX24	safety switch	1	serial	voltage	on/off
	PX24	purity control	2	serial	complex	bit pattern
	detector	primary inlet and outlet gas temperature	28	analog	temperature	R
	detector	primary inlet and outlet pressure	28	analog	pressure	R
	detector	primary inlet and outlet gas flow	28	analog	flow	R