Appendix A: ECAL DCS – High precision temperature monitoring.

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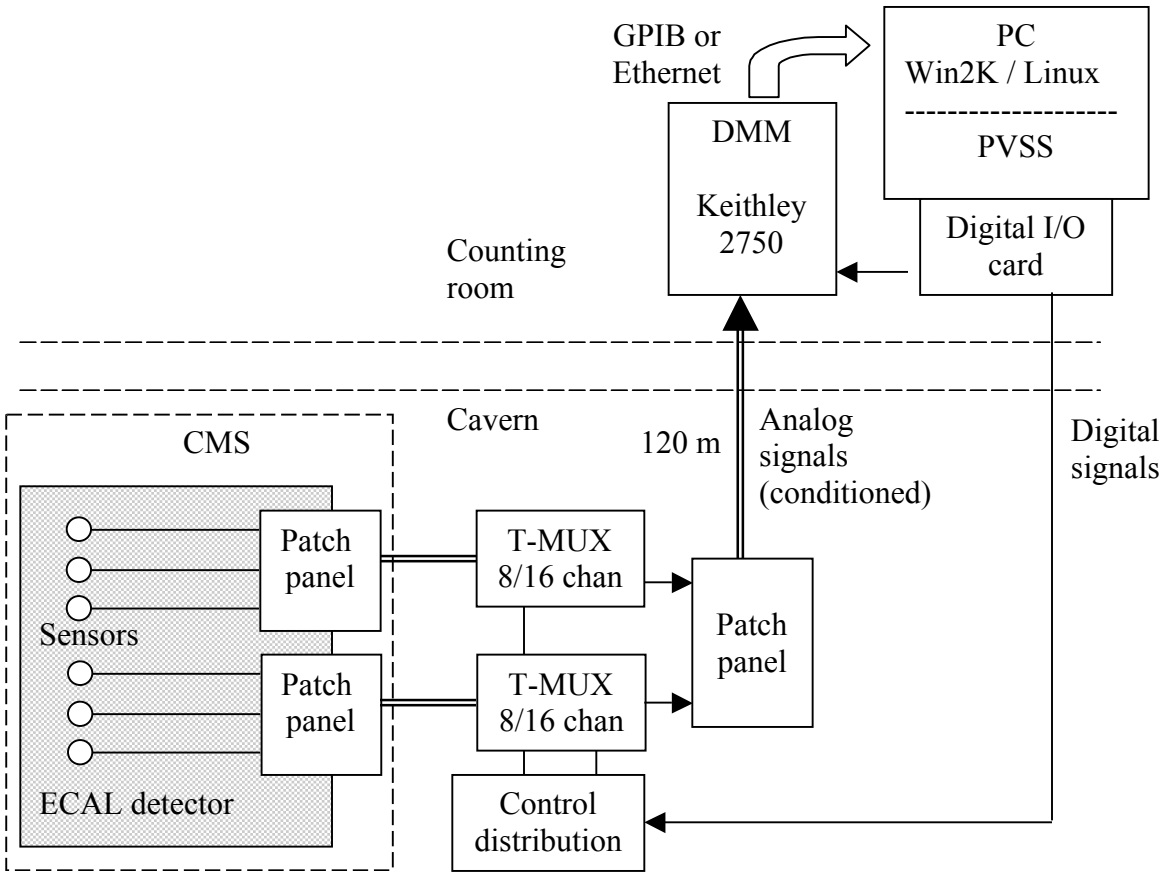
Task: constant precision monitoring of temperatures inside the thermal screen.
Operation: continuous (non-stop) 24h/day, 365d/y.
Precision: better than 0.01°C (relative)
No. sensors: ~ 500 (EB + EE).

Sensor location:
Sensors are distributed in two layers inside the thermal screen:
-- outer layer (on the grid, 4x sensors per SM -- EB)
-- inner layer (on crystals, 4x sensors per SM -- EB)
-- one sensor each at the cooling circuit In-and Output of a SM

General layout:
Sensor signals are conditioned with local multiplexing transducers (T-MUXs, located in the cavern, close to CMS) and then transmitted to the counting room – there, signals are digitized with a multichannel multimeter (Keithley 2750) and the data are sent to a PC, which runs the PVSS SCADA software. The PVSS temperature monitoring application provides regular data acquisition, data visualization and archiving. Also, it provides alarm and warning messages if temperature goes out of the predefined limits.



Sensors: NTC thermistors
Type: Betatherm BetaCurve, 100K6A1B (or 10K3A1B)

Sensor probes and signal cables:
Sensor packages are fragile, so sensors are to be mounted in rigid probes. Probes also provide the connection of sensor leads to an individual signal cable (2-3 m), which runs to a patch panel (see the figure above). From the patch panel, a multi-conductor (STP) cable runs to a T-MUX.

Front-end electronics:
A multiplexing transducer module (T-MUX), to be designed specifically for temperature measurements, provides sensor excitation and raw signal conditioning for 8/16 sensors.
A T-MUX module includes an analog multiplexer for 8/16 channels and a single channel transducer ASIC. The latter contains a current source (1/10/100 μA), a differential amplifier, a voltage reference (2.5 V), and control logic. It provides a differential voltage (0 – 2.5 V) output signal. Sensor excitation is achieved via DC current, 1 or 10 μA (V_{max} ~ 1.2 V).

The ASIC (developed the for LHC cryogenics controls [1]) provides high precision resistance measurements; for each point several measurements (max 8) can actually be performed:

- sensor resistance;
- (external) reference resistance;
- sensor/reference with reversed signal at the amplifier input;
- sensor/reference with reversed polarity of the current source.

This allows each resistance measurement to be auto-calibrated and removes drift errors.

The ASIC is designed and successfully tested for use in radiation environments. However, analog multiplexers are not certified for radiation environments. It is assumed that after some period (several years) of operation these should be replaced in order to guarantee their characteristics. To facilitate replacement, analog multiplexers are placed on a small PCB, which is plugged on the T-MUX module PCB. However, it is worth noting that alternative radiation-hard multiplexer are currently looked for, which would not have to be replaced.

[1] -- RBFE ASIC M.A.Rodrigez Ruiz et.al.
Radiation tolerant instrumentation for the LHC cryogenic system.
RADWG Day, 7.Dec.01, - see http://lhc-radwg.web.cern.ch/LHC-radwg/

Data acquisition electronics:
Analog signals from the T-MUX modules are digitized with a high precision (22 bit) multichannel DMM (digital multimeter), Keithley 2750. This device supports up to 200 input channels with plug-in analog multiplexer modules. Thus, a complete temperature

monitoring application (~ 500 channels) can easily be built with a single K-2750; moreover, other applications could use (share) it too – e.g., humidity monitoring.
K-2750 can be connected to a PC via either GPIB or Ethernet. A software driver, supplied together with the K-2750, is interfaced to PVSS via a customized PVSS component (API manager).

PVSS application:
The application includes a set of PVSS panels and scripts (also, an API manager to connect to the K-2750 DMM). It provides operation and configuration/maintenance services.
Operation services are data acquisition and visualization; generating alarms and warnings when temperature goes high or low; data archiving. Data are also available to CMS/ECAL DAQ via the "standard" PVSS—XDAQ interface.
Configuration/maintenance services are intended for expert users; these include system configuration and calibration procedures, dealing with faulty hardware, changing channel scanning parameters, etc.

Remark:
It is important to note that an alternative readout scheme, based on the ELMB (Embedded Local Monitoring Board) developed by ATLAS, and successfully tested in the M0' testbeam during summer 2002, is still considered as a possible backup solution in case serious problems are encountered with the Keithley option.