Environmental stress screening of the CMS ECAL Barrel VFE and LVR cards

Authors

Peter Adzic[A], Christian Bernier[D], Lazar Cokic[A,B], Günther Dissertori[C], Tomasz Gadek[C], Werner Lustermann[C], Milorad Mijic[A], Predrag Milenovic[A], Nikola Rasevic[A] on behalf of the CMS collaboration

[A] Faculty of Physics, University of Belgrade, Serbia
[B] CERN, Switzerland
[C] ETH Zurich, Switzerland
[D] Northeastern University, USA

Abstract

In preparation for the operation at HL-LHC the electronics of the Electromagnetic calorimeter Barrel must be replaced. 12240 new very front end (VFE) cards will amplify and digitize signals of 62100 lead-tungstate crystals instrumented with avalanche photodiodes. 2448 low voltage regulator cards provide power for the VFE and digital interface cards. Reliable operation of these cards with failure rates as low as 0.5% at the end-of-life, after ~20 years, is targeted, requiring environmental stress screening (ESS). We present the implementation of the hardware and software components of the custom developed ESS system, highlighting its modularity, configurability, flexibility, and scalability.

Summary

In preparation for its operation at CERNs High Luminosity Large Hadron Collider, the Compact Muon Solenoid (CMS) experiment [1] is undergoing an extensive upgrade program. The Electromagnetic calorimeter Barrel (EB) [2] of CMS is made of 61200 lead-tungstate crystals read out by avalanche photodiodes. Its readout electronics are arranged into readout towers (RTs) of 5x5 channels, each RT comprising five very front end (VFE) cards, one digital interface card (FE) and one low voltage regulator (LVR) card conditioning the power of that tower. The entire on-detector and off-detector electronics, comprising 12240 VFE, 2448 FE and 2448 LVR cards, will be replaced [3].

EB is a single layer detector, where missing readout channels degrade the energy resolution and missing towers may allow photons or electrons to remain unidentified. Extracting an EB module for repair requires several months and is not foreseen for the operation period of ~20 years. Consequently, we aim at excellent quality and reliability targeting <0.5% of failing readout channels at end-of-life. This will be achieved and assured among others by Environmental Stress Screening (ESS) of all cards prior to their installation into EB.

We have built a dedicated ESS system for performing thermal cycling between ambient temperature and ~70 °C with VFE and LVR cards simultaneously. This approach assures proper powering of the VFE cards and the correct load for the LVR cards. The system design is modular. Twelve identical boxes host 9 RTs each, enabling simultaneous testing of 540 VFE and 60 LVR cards. Thermal cycling is achieved by powering the electronics on and off together with fans controlling exchange of air between the box and the ambient. Additional fans inside the box create a homogeneous air temperature within ~5 °C inside the box. Fan speeds and thus temperatures are controlled by STM32 Arm Cortex®-M microcontrollers. Monitoring of temperature is obtained by reading existing temperature sensors on the VFE and LVR cards using Keithley DAQ6510 equipped with Keithley 7701 multiplexing cards. Power is provided by programmable TDK Lambda power supplies. A Siemens

programable logic controller monitors temperatures inside all boxes using independent PT1000 sensors and provides safety interlocks to power supplies in case of over-temperature, enabling safe unattended operation of the system.

The software for monitoring and control of the ESS system is built in a highly modular, configurable, and scalable way using public Python libraries (pyVisa, pySerial, python-can, python-snap7, RPyC, PyQt, PyMySQL). It comprises multiple data/information subscription services and clients for monitoring/operation/control of the system and includes the graphical user interface and interface to an SQL database where all test data will be stored.

We will use the system to measure the failure rate of eight RTs versus time for several months with a minimum of 200 power cycles. This measurement will provide the information about reliability of cards and allow to estimate the aging period, T_a, required to reject cards with early failures. During production of VFE and LVR cards we will use the system to screen all cards for one period T_a.

References:

[1] CMS Collaboration, G.L. Bayatian et al., “The Compact Muon Solenoid: Technical Proposal”, CERN-LHCC-94-38, CERN-LHCC-P-1, Dec. 1994

[2] CMS Collaboration, G.L. Bayatian et al., “The Electromagnetic Calorimeter: Technical Design Report”, CERN/LHCC 97–33, Dec. 1997

[3] CMS Collaboration, A.M. Sirunyan et al. “The Phase-2 Upgrade of the CMS Barrel Calorimeters: Technical Design Report”, CERN-LHCC-2017-011, CMS-TDR-015, Sep 2017

Additional material:

The following material comprises three figures that present the schematic representation of the environmental stress screening (ESS) system components (figure 1), an illustration of the components used for the testing of the ESS prototype (figure 2), and Siemens programable logic controller setup used for the ESS system.

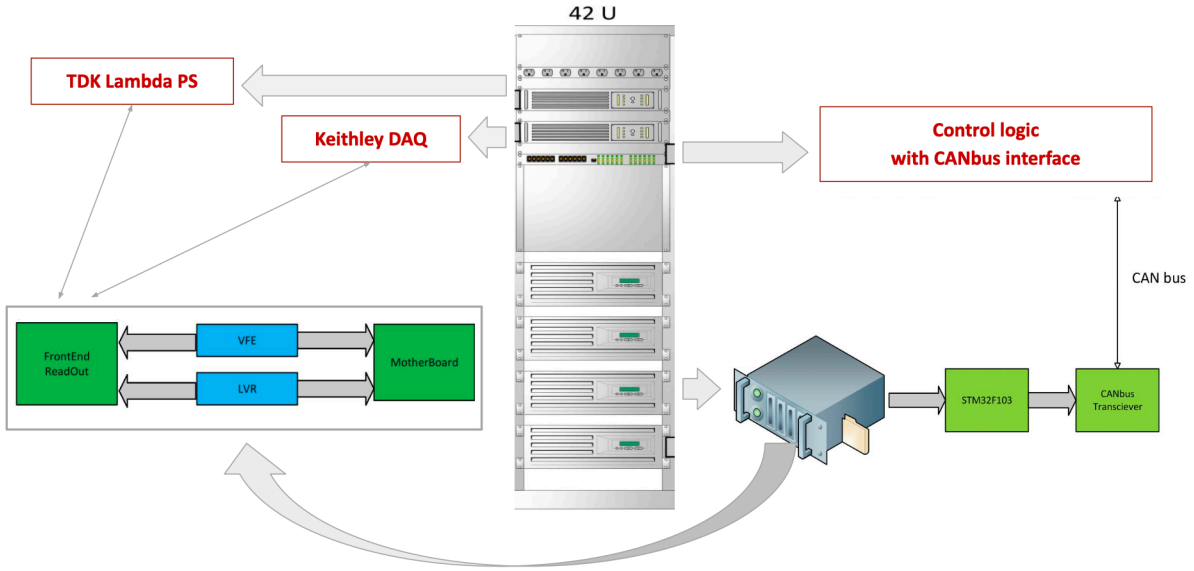

Figure 1. Schematic representation of the components of the Environmental stress screening system and their logical interconnections as hosted within one rack. The system in total contains 12 identical boxes that host 9 readout towers each, enabling simultaneous testing of 540 VFE and 60 LVR cards. Temperatures of the cards are monitored using Keithley DAQ6510 system, power is provided by programmable TDK Lambda power supplies, while internal fan speeds and thus temperatures are controlled by STM32 Arm Cortex®-M microcontrollers. The system is distributed in three 42U racks, while a separate rack hosts the system with Siemens programable logic controllers that provide safe unattended operation of the system.

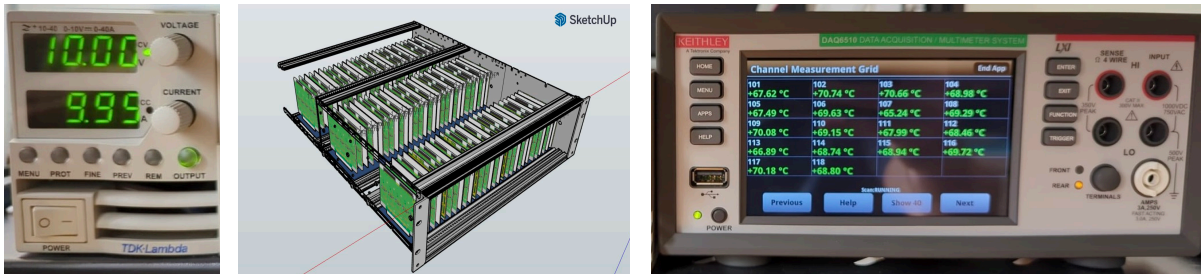

Figure 2. An illustration of the components used for the testing of the prototype of the Environmental stress screening system using: one TDK Lambda power supply (photo on the left), one box with 9 readout towers with mockup cards that have the power consumption & dissipation as expected in the final VFE and LVR cards (3D model in the center), and one Keithley DAQ6510 system used to monitor the temperature of the electronics cards (photo on the right). The temperature readout shows the stability of the temperatures within ~5 °C inside the box.

Figure 3. Siemens programable logic controller setup used for the Environmental stress screening system, in order to independently monitor temperatures inside all 12 boxes using PT1000 sensors and to provide safety interlocks to power supplies in case of over-temperature, enabling safe unattended operation of the system. The system is based on the design of the safety system that will be installed at the upgraded CMS experiment and provide safe operation of the EB detector during the operation of the HL-LHC.