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Production, Quality Control and Performance of VFAT3 Front-end Hybrids for the CMS GE1/1 Upgrade

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CMS is planning to install GEM chambers as part of the Muon upgrade for High Luminosity Operation at the LHC. The front-end ASIC (VFAT3) has been produced in volume together with its hybrid PCB. This paper describes the design of a custom test bench for the production Quality Control (QC) of the VFAT3 hybrids. The full QC procedure incorporates calibration and performance measurements, database entries and statistical data analysis. The paper details the optimization of firmware and software functions reducing the test time per hybrid from 30 to 1.2 minutes. Pre-Series production of 1000 hybrids shows a yield of 94%.

Summary

VFAT3 is the Front-end ASIC specifically designed for the readout of gaseous detectors within the CMS experiment during the high luminosity upgrade of the LHC at CERN. VFAT3 characterization and hybrid production QC is a compulsory demand for the GE1/1 chambers installation. A custom test bench is designed for VFAT3 characterization and hybrid production testing for the GE1/1 detectors. This platform consists of a Kintex-7 evaluation board, a custom Verification board, a Handheld IR Temperature Gun, a Barcode Scanner, a Power Supply and a Linux PC with test software. The Verification board is connected with the FPGA platform through FMC VITA standard and has onboard power monitoring features. The firmware is based on a System-on-Chip (SoC) architecture with Microblaze processor connected to the Verilog HDL peripherals within the FPGA through Advanced Extensible Interface (AXI) bus architecture. The firmware communicates with VFAT3 through Scalable Low Voltage Signaling (SLVS) at 320 Mbps. The software is designed with Python and the graphical interface is built using TkInter GUI package. The software controls the firmware and other USB peripherals and communicates with the test system through a 1-Gbps TCP/IP interface. Through the test system, the software provides two unique modes. First, one is an interactive mode and is solely utilized for debugging and characterization of the hybrid. The second mode is a production interface, which runs a predefined set of tests and APIs that are needed for the production testing of the hybrid. The production interface requires minimal operator intervention and is user-friendly. The existing test bench was unable to test large volumes of the VFAT3 hybrids, so an extensive upgrade was done to implement complex computing and iterative blocks in the firmware. This helped to reduce the full production test time per VFAT3 hybrid from 30 minutes to 1.2 minutes. The production testing of each hybrid performs several high-level tests including S-Curves and DAC Scans. The results of these routines are compared against predefined selection criteria, which defines a green, yellow or red hybrid. These results are then gathered to decide if the tested hybrid is suitable for GE1/1 production or if it should be discarded. An automatic link to central MySQL is also established for production data storage and retrieval of the hybrid parameters during the CMS experimental run. A pre-series of 1000 hybrids have been tested and the data are statistically analysed to detect the nominal VFAT3 parameters for GE1/1 operation. The common production failure causes are also understood, like broken ADCs, dead/noisy channels and hybrid-short. An overall yield of more than 94% is achieved from VFAT3 production platform.

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