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Beam Phase and Intensity Monitor for the LHCb experiment

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The LHC RF clock is transmitted over kilometres of fibre to the experiments where it is distributed to thousands of front-end electronics boards. In order to ensure that the detector signals are sampled properly, its long-term stability with respect to the bunch arrival times must be monitored with a precision of <100ps. In addition it is important to monitor the LHC bunch structure and the trigger conditions by measuring the intensity of each bunch locally in the experiment.
For this purpose a beam phase and intensity acquisition board (BPIM) is being developed for the Button Electrode Beam Pickups which will be installed on both sides of all the LHC interaction points. The board measures the two quantities per bunch, and processes and histograms the information in an onboard FPGA. The information is read-out by the Experiment Control System and directly fed to the LHCb Timing and Fast Control system.

Summary

The LHC bunch clock frequency of 40 MHz is transmitted to the experiments via a network of optical fibres which is partly based on non-phase-stabilized fibres. In the case of the LHCb experiment the non-phase stabilized distance is about 4.6km. In LHCb the bunch clock is locally distributed by the Timing and Fast Control system to all the detector front-end electronics where it is used to sample the detector signals. In order to sample the detector signals, which typically have a maximum plateau of a nanosecond, at the optimum point, the timing system provides several means of making a complete timing alignment at the level of 50ps. Since the LHC fills are expected to last for more than ten hours, it is of extreme importance that the phase of the LHC clock remains stable with respect to the bunch arrival times. However, several effects such as temperature variations influence the phase. Measurements show that the time drift on the transmission fibres could be as large as 200ps over a period of 24 hours, and up to 8ns have been observed over a period of a year. Clearly the phase must be monitored and regular timing alignments must be performed.

In order to monitor the bunch arrival times with respect to the clock a special Button Electrode beam pickup will be installed 180m away from the interaction points on each side. Since the pulses of the four buttons of each pickup will be summed, the signal per crossing becomes independent of the position of the beam and thus also allows measuring the currents of the bunches. This is of high interest since the LHC bunch structure can be monitored and the bunch currents can be correlated with the actual physics triggers.

The current paper proposes a beam phase and intensity acquisition board (BPIM) capable of performing the two measurements per bunch crossing. The analogue unit of the board consists of a separate circuit for the phase measurement and the intensity measurement. Since the shape and the amplitude of the pulse will vary, the phase measurement circuit contains a special pulse detect circuit which is independents of the shape, and the intensity measurement circuit contains a programmable gain amplifier. The digital processing of the board is based on an FPGA which performs response linearization, averaging and histogramming in the memory of the FPGA of the measurements. The control interface is based on an embedded Credit-Card-sized PC from Digital Logic. The controller has Ethernet and is one of the standard interfaces to the Experiment Control System in LHCb. The control of the analogue circuits, such as gains and thresholds, is handled through the FPGA. In addition to reading out the measurements via the control interface, they are also output on the

front-panel of the board at 40MHz with LVDS. The latter allows directly interfacing the board to the Timing and Fast Control system in order to add the bunch current information to the data of each event.

The board is in development. A first full design has been made and simulated. One of the authors has also implemented and tested the design in the context of an intensity monitor for the CERN PS accelerator.

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