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Study of the hybrid controller electronics for the nano-stabilisation of mechanical vibrations of CLIC quadrupoles

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In order to achieve the required levels of luminosity in the CLIC linear collider, mechanical stabilization of quadrupoles to the nanometre level is required. The paper describes a design of hybrid electronics combining an analog controller and digital communication with the main machine controller. The choice of local analog control ensures the required low latency while still keeping sufficiently low noise level. Furthermore, it reduces the power consumption, rack space and cost. Sensitivity to single events is reduced compared to a digital controller. The digital part is required for fine tuning and real time monitoring via digitalization of critical parameters.

Summary 500 words

In the Compact LInear Collider (CLIC) currently under study, electrons and positrons are accelerated to collide with energy up to 3 TeV. To achieve the required levels of luminosity, the vertical beam size is 1 nm at the interaction point. About 4000 main beam quadrupoles, mechanically stabilized to the nanometre level, are needed to achieve that. To this purpose, an active stabilization system is being developed.
As a first requirement, the stabilization system electronics should have high resolution and low noise. Secondly, because of controller stability and performance, the latency of the controller must be in the range of micro seconds. This implies local controllers, limiting the cable induced noise and the delay created by optical fibres over several kilometres. In a previous feasibility demonstration, sub-nanometre stability was achieved on test benches using a flexible commercial real time PXI controller with an 18 bit acquisition card through digital signal processing, reaching a latency of about 40 µs. However, major drawbacks exist. The CPU requires significant power in a tunnel that has a tight limit for heat loads. In addition, many of its components are not radiation tolerant, and it has a relatively high cost per channel if latency is to be kept low for performance. Finally, as a general concern for digital solutions, there are currently no commercially available ADC/DAC components with the required resolution that are radiation and single event resistant.
Therefore, a custom vibration stabilization electronic controller was designed with commercially available components. It is a hybrid circuit, composed of a fully analog controller and a digital communication part. Although typically noise adds up with each component in an analog chain, an acceptable signal to noise ratio was achieved for a limited number of components by following a careful design. A comparison is made with the digital controller mentioned above. It can be seen that while the digital one is more flexible and has a higher signal to noise margin, there is a strong penalization in performance due to delay. Better stabilization results were obtained with the small latency of the analog controller; and a vertical stability well below 1 nm integrated R.M.S. displacement was reached at 1 Hz.
The digital part of the circuit has a communication role. It introduces some flexibility for the stabilization by allowing remote fine tuning of the analog circuit. It also monitors operational parameters and communicates with the main accelerator controller. Due to its lower resolution requirements, commercially available radiation hard ADC/DAC components can be used. Finally, an assessment of the stabilization electronics strategy and the performance at the current development status is presented.

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