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Concept, realization and characterization of serially powered pixel modules

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We demonstrate here for the example of the large scale pixel detector of ATLAS that Serial Powering of pixel modules is a viable alternative powering scheme that have been devised and implemented for the modules using dedicated on-chip voltage regulators and modified flex hybrid circuits. The equivalent of a pixel ladder consisting of six serially powered pixel modules with about 0.3 Mpixels has been built and the performance with respect to noise and threshold stability and operation
failures has been studied. We believe that Serial Powering in general will be necessary for future large scale tracking detectors.

Summary

Large scale and high granularity tracking detectors are usually built from many identical modules which operate individually. Such modules can then be optimized in performance and power consumption. The usual scheme of parallel powering every module
with a constant voltage is disadvantageous for the performance of the detector as a whole. Above a certain granularity the power losses in the cables easily exceed the actual power consumption of the modules, especially if the readout chips need a low supply voltage, but have a high power density at the same time.
Moreover a vast amount of cables is needed to power such a large scale detector. The cables are in the way of the particles that are tracked and lower the originally optimized performance of the module and of all following detectors.
For the LHC experiments this already now is a major problem for the optimal performance of the detectors and it has become evident, that for an upgrade program alternative powering schemes must be investigated.

We prove and demonstrate here for the example of the large scale pixel detector of ATLAS that Serial Powering of pixel modules is a viable alternative. A powering scheme that powers a chain of modules with a constant current and uses dedicated on-chip voltage regulators and modified flex hybrid circuits has been devised and implemented for ATLAS pixel modules.
The implementation of Serial Powering is the serial connection of a ladder of 13 modules. An example calculation shows that such a chain of 13 modules offers a reduction in power losses of the cables by 90% and a reduction in passive materials by 98%, this is a reduction of 85% in radiation length.
Prior to building serially powered modules the characteristics of the voltage regulators, namely shunt and linear regulators, as the key elements to this powering scheme were measured on over 250 chips of a current production wafer. It has been shown that the spread in quality is small and the voltage stability of the linear regulators is excellent, so that the voltage regulators are applicable for Serial Powering.
The serially powered modules have been intensively tested in the lab and in test beams. The comparison between parallely powered and serially powered modules with respect to noise and threshold stability performance have shown no difference between the two powering schemes. Finally the equivalent of a pixel ladder consisting of six serially powered pixel modules with about 0.3 Mpixels has been built and the performance with respect to operation failures has been studied. The major objection against Serial Powering is the possible noise pickup by modules through the power lines. Measurements with artificially noisy modules mimicked by

inducing noise on the power lines have only shown a marginal increase in noise of the other modules in the chain. We therefore strongly believe that Serial Powering is not only a viable powering scheme for an upcoming upgrade of the ATLAS pixel detector, but is also viable, if not absolutely necessary for future large scale tracking detectors. The presentation will show the scheme, the design of the necessary components and the measurements.

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