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Pulsed power distribution for power supply isolation and remote 2-wire point-of-load regulation for the ATLAS Pixel Detector

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High common mode offset voltages can arise in the ATLAS Pixel detector module communication links that could prevent new Pixel Detector modules from taking data because of the present grounding and power supply schemes. Isolation of all the detector module electronics supply channels eliminates this risk. We propose that it is possible to provide inexpensive, reliable and serviceable power channel isolation by exploiting the ac characteristics of the installed ATLAS Pixel power distribution system. We also show how it is possible to achieve remote, 2-wire point-of-load voltage regulation by using pulsed power over existing Pixel cables.

Summary

The present ATLAS Pixel Detector shares each power supply channel across 6 or 7 detector modules, although cables are installed for each module power supply channel all the way to the power sources in the rack rooms, 80 m away from the detector. This power supply channel sharing breaks the electrical isolation among each group of modules.

By itself, this power channel sharing doesn't create a problem for detector operation but the Pixel grounding scheme includes a common point on each detector module for the return circuits of the digital power supply and analog power supply channels required for module operation. Futhermore, all the digital supply return lines are connected to a common grounding point in the detector package.

Under high beam luminosity conditions that require currents greater than 1 A in the digital supply for a module, this power sharing and grounding scheme can lead to return current paths that cause significant voltage offsets between the optical readout circuits and those same 6 or 7 modules in a group that are sharing a power channel. This offset can disrupt communication with the module, causing its loss for data taking. The new electronics to be installed with the next Pixel Detector upgrade, presently under construction, have a much more limited common mode offset voltage range than the currently installed detector modules, which will continue operating in the upgraded detector.

We present a proposal for economically achieving low voltage power supply isolation for each ATLAS Pixel Detector module electronics power supply channel by using an isolated ac power signal to drive the existing Pixel cable plant. Besides providing individual channel isolation, this method offers the possibility to limit the risk of damage to the Pixel detector module elecronics from the failure of the nearby voltage regulator. We further show that it is possible to design an ac power isolation system by adding circuitry to the existing power distribution equipment in a way that doesn't require rewriting complex operation and monitoring software programs.

Results are shown for lab tests with a 100 m sample of the digital power cable used in the ATLAS Pixel Detector. The time response has been measured for various loads, power source frequencies and currents. The frequency response of the isolated power system is predicted by simulations and verified by S-parameter measurements of the cable sample.

The requirements to fully develop the proposed isolated power system are presented. This includes the limitations of the electronics simulators normally used for electronic designs involving transmission lines and suggests methods for working around these limitations. Evaluation of power source frequencies and signal shapes for ac power distribution in terms of efficiency, cost and safety for the Pixel Detector modules are also included.

Additional advantages arising from implentation of the proposed isolation technology are demonstrated, including improved transmission efficiency and lower maintenance costs, as compared to the present Pixel power distribution system.

In the present ATLAS Pixel Detector power distribution system there is a risk that under high current operating conditions, a common mode offset voltage can develop between a Pixel detector module and its optical communication system, which receives and transmits data for module readout and operation. This offset can be high enough to cause upgrade module electronics, which operate with lower offset voltage ranges, to be inoperable with the installed Pixel modules, as was learned in the recent Pixel project to reconstruct and modify parts of the existing Pixel Detector package. Another instance of mixing new electronics with the existing detector module electronics comes with the Pixel Detector upgrade presently under construction, which will add a new layer of detector modules.

Providing electrical isolation for each power supply channel on each module eliminates the risk of disruptive offset voltages arising between the existing Pixel Detector module electronics and new modules operating with a more limited common mode offset voltage range.

Currently, voltage regulators near the ATLAS pixel detector are used, however, upgrades to the LHC will lead to a radiation environment that is too high to allow this configuration. The present Pixel power distribution system also carries a risk of subjecting a module's electronics to damaging voltage levels should the nearby voltage regulator fail. There are other limitations that arise for the design of voltage regulators to be used in an area of high radiation, limited heat removal capacity, highly restrictive mass limitations for physics reasons and little to no possibility to gain access for maintenance.

The advantages of achieving reliable remote point-of-load voltage regulation on detector modules for the high luminosity Pixel upgrade are clear.

We propose to exploit the ac transmission line characteristics of the installed Pixel power distribution system to achieve electrical isolation of each of the electronics power supply channels on each Pixel detector module. It is shown through lab tests of real Pixel Detector components, and on a scaled down Pixel detector, that electrically isolated ac powering of the installed power distribution system can be cost effective, reliable and efficient.

Furthermore, we show that another benefit of ac power distribution can be precise remote point-of-load regulation for future Pixel Detector module electronic designs over the same two wires that deliver power to the detector module electronics. Test results are shown that demonstrate the feasibility of remotely sensing the precise voltage at a power supply channel point-of-load –the detector module electronics –by use of ac power distribution over existing Pixel power cables. It is shown that this can be done without using inductors within the very large magnetic fields of ATLAS. Because the point-of-load voltage can be accurately monitored across the 80 m length of a Pixel power distribution system, the remote voltage regulator circuitry can be located in the rack rooms, which can be much more easily accessed for maintenance than can the hall where the ATLAS Detector sits and where the regulator is safe from exposure to damaging radiation.

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