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Nuclear Instruments and Methods in Physics Research A 579 (2007) 844–847

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

Serial powering of silicon strip detectors at SLHC

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Available online 31 May 2007

Abstract

Serial powering is a technique to power a large numbers of detector modules using a single power cable and a constant current source. Module power is derived using local shunt regulators. Serial powering is of great interest for large-scale silicon tracking detectors for particle physics with many thousands of densely packed detector modules. We have been operating six ATLAS Semiconductor Tracker (SCT) modules using both serial powering and conventional independent powering. The modules operated stably with no indication of any extra noise sources. We present selected results and discuss the system aspects of serial powering.

PACS: 29.40.Gx; 29.40.Wk

Keywords: Solid-state detectors; Silicon detectors

1. Introduction

The Large Hadron Collider (LHC) at CERN, Geneva, will be upgraded to the Super LHC (SLHC) to provide a 10-fold increased luminosity by the year 2015. The silicon trackers of the LHC experiments will then be at the end of their life time and will need to be replaced. The future ATLAS tracker for SLHC will be an all-silicon tracker with an inner pixel region surrounded by silicon micro-strip detectors. It will consist of 30–60 million strips with a total sensor area of between 150 and 200 m^2.

The new tracker will be an object of unprecedented technical complexity. One key challenge is the distribution of power to the front-end electronics. In current silicon tracking systems, each detector module is powered independently. The current ATLAS Semiconductor Tracker (SCT) [1], for example, requires several thousand power cables. The cable length exceeds 80 m (one way) and resistance (including return) is several Ohms. This luxury can no longer be afforded for ever larger and denser tracking systems. Independent powering fails because

1. There is no space for a 5- or 10-fold increased number of power cables.
2. The power efficiency is too low. More than 85% of the total power could be lost in the cables.
3. The material represented by the power cables leads to excessive multiple scattering and creation of secondary particles. Note that the current on detector power flex circuits present 0.2% of a radiation length for one layer of SCT barrel modules at normal track incidence.
4. The number of cables causes severe packaging and interconnection constraints for detector modules or supermodules.

Serial powering provides an elegant solution to each of these problems.

2. Serial powering

Serial powering has been reported for ATLAS pixel modules with most encouraging results [2]. Its application to strip sensors is more critical due to the larger noise sensitivity and the size of silicon strip detector systems [3].

A serial powering system for silicon detectors consists of four elements: a current source; a shunt regulator and power device (for digital power); a linear regulator (for analog power); and AC or opto-coupling of clock, command and data signals.

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0168-9002/$ - see front matter
doi:10.1016/j.nima.2007.05.290

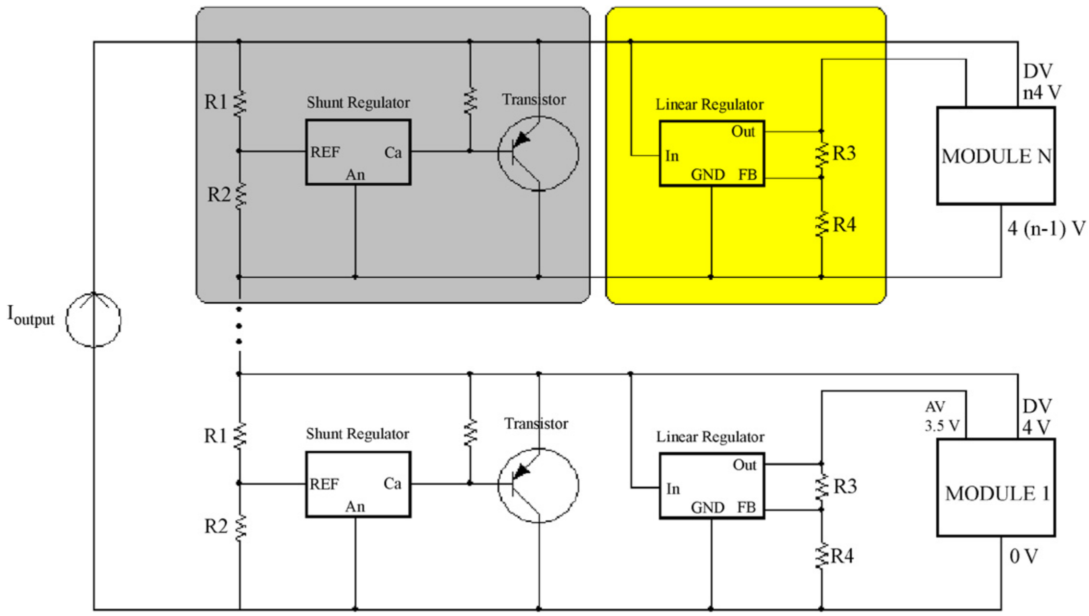

Fig. 1. Example of a *serial powering* scheme. Analog and digital power are derived by regulators on each module. In this example, the module operation voltage is assumed to be 4 V as for SCT. (For SLHC, the module voltages will be reduced to approximately 1.5 V.)

The modules are all chained in series as sketched in Fig. 1. The number of long cables is reduced by a factor of $2n$, if n modules are powered in series. (The factor 2 arises from using a single power supply to derive analog and digital voltage rather than providing them separately.)

Each module sits at a different potential and the total voltage across a series of n modules is n times the *module voltage*. The current needed to power the total chain is simply the module current plus the (small amount of) current lost in the regulators. Note that analog ground, digital ground and sensor bias ground are tied together on the module, as is common practice for independent powering as well. Since the grounds of different modules are different, floating HV power supplies must be used.

Serial powering can be much more efficient than independent powering since thermal losses in cables are reduced by a factor of n. The power efficiency for serial powering is $1/(1+IR/Un)$, while for independent powering it is $1/(1+IR/U)$, where I is the module current, R is the cable resistance, and U is the module voltage. For an SLHC tracker, typical values of R, I, and U would be $R=4\,\Omega$, $I=2.5\,\mathrm{A}$, $U=1.5\,\mathrm{V}$. This implies that only 13% of the delivered power would reach the module for independent powering. This is unacceptable for a tracker using at least $\approx 100\,\mathrm{kW}$ of module power. Serial powering greatly improves efficiency. With the above assumptions and powering 16 modules in series, power efficiency reaches 70%, reducing the total power by a factor of five.

3. Set-up with SCT modules

In order to test serial powering with SCT modules [4], we have built a serial powering interface board, which connects to an SCT module on one end and to the DAQ

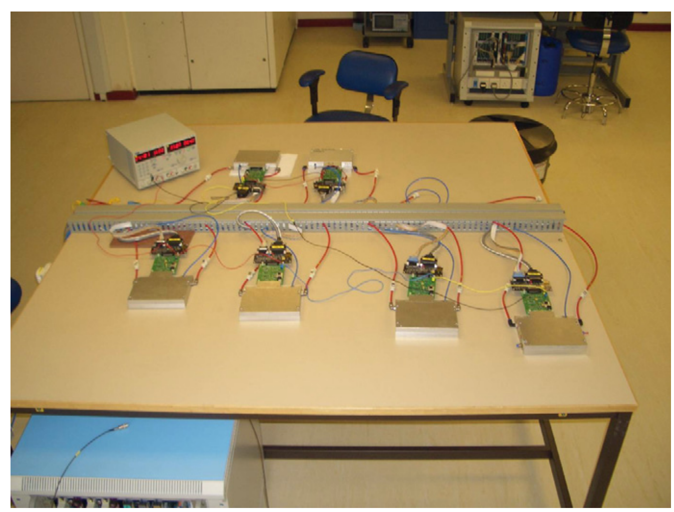

Fig. 2. Serial powering set-up with six SCT modules, serial powering interface board, DAQ support cards and a constant current source in the RAL clean room.

(support card) on the other. The board is realized as a two-layer printed circuit board (PCB) and uses commercial packaged ICs to implement the regulator and other circuitry. Control, clock and data signals are AC coupled. A photograph of the set-up is shown in Fig. 2.

The board was not optimized for size, but a smaller $38\times 9\,\mathrm{mm}^2$ large version was also built to implement serial powering in a highly integrated supermodule (see Ref. [5]). The small board uses bare die ICs and is realized as a four-layer PCB. Increased miniaturization will be achieved if serial powering circuitry is placed directly on the read-out hybrid and if custom (radiation-hard) ICs become available.