Multichannel System of Fully Isolated HV Power Supplies for Silicon Strip Detectors

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Abstract

A multichannel system of power supplies providing a bias voltage in the range of 0 - 410 V for silicon micro-strip detectors is presented. All channels are fully isolated allowing for flexible detector segmentation. A wide range of functions including e.g. a programmable current trip limits as well as a ramp-up and ramp-down control independent for each channel are also described.

I. Introduction

Silicon micro-strip detectors operating in the LHC high radiation environment require the bias voltage which could be adjusted in a wide range. For the ATLAS SCT in particular [1] the required variation is from 0 to 410 (500) [1] V.

The ATLAS silicon micro-strip detector [3] is fairly modular and it has been decided that the modularity of the SCT voltage power supply system follows the modularity of the detector. Consequently, each of 4088 detector modules is equipped with its HV (as well as LV) power supply module. In addition it has also been decided that power supply modules are fully isolated to allow for the maximum flexibility at the final selection of the shielding and grounding scheme of the experiment.

II. General characteristics of the ATLAS SCT HV system

The system [2] consists of cards each of which contains several single isolated modules (channels). The system is build in two similar versions. The full VME version for laboratory applications in small centers testing modules of silicon strip detectors. In this version a standard 6U card consists of four independent power supplies. The version for the final detector system of the ATLAS experiment uses standards of VME mechanics but a custom back plane and crate control. In this version eight HV channels are packed on each card.

The system provides digitally controlled stable bias voltage in 0 - 410 (500) V range and a precise measurement of the output current. A maximum load of each channel is 5 mA. A current trip limit can be set independently for every channel in the range from hundreds of nA to the maximum of 5 mA. Another parameter which can be selected individually for each channel is the ramping speed with which the nominal voltage change is executed. Ramping speed is digitally controlled can be selected from a very wide range.

Single channel functions are controlled by programmable microprocessor which communicates with a programmable card controller via fast serial link.

Communication with the crate controller for the VME version uses standard addressing mode. In the final production version this communication is realized with a fast custom parallel link. Reaction times of processors to various conditions like requirement of a new setting, over-current and over-voltage trips etc. are well below 1 ms.

III. Card Description

One 6U card of the multichannel system of HV power supplies contains four identical channels (or eight for the final design). Another elements located on the card, which serve all channels, are: the card controller, the interface to the crate bus and circuits responsible for the distribution of power supplied by the power pack of the crate.

A. Card Controller

The ATMEL flash microprocessor AT89C52 is used as the card controller. It receives commands from the crate controller and communicates with microprocessors of all channels located on the card. Communication with channels is realized via internal serial interfaces operating in the full duplex mode, asynchronously at 2 Mbaud rate. Transmission of bytes between card controller or channel controllers is buffered and serviced with the help of interrupts.

B. Card Addressing

For the full VME version the standard addressing mode is used. The card address corresponds to the eight VME address lines (A16 - A23) and can be set via the dip switch

[1] The upper limit requirement is still under debate

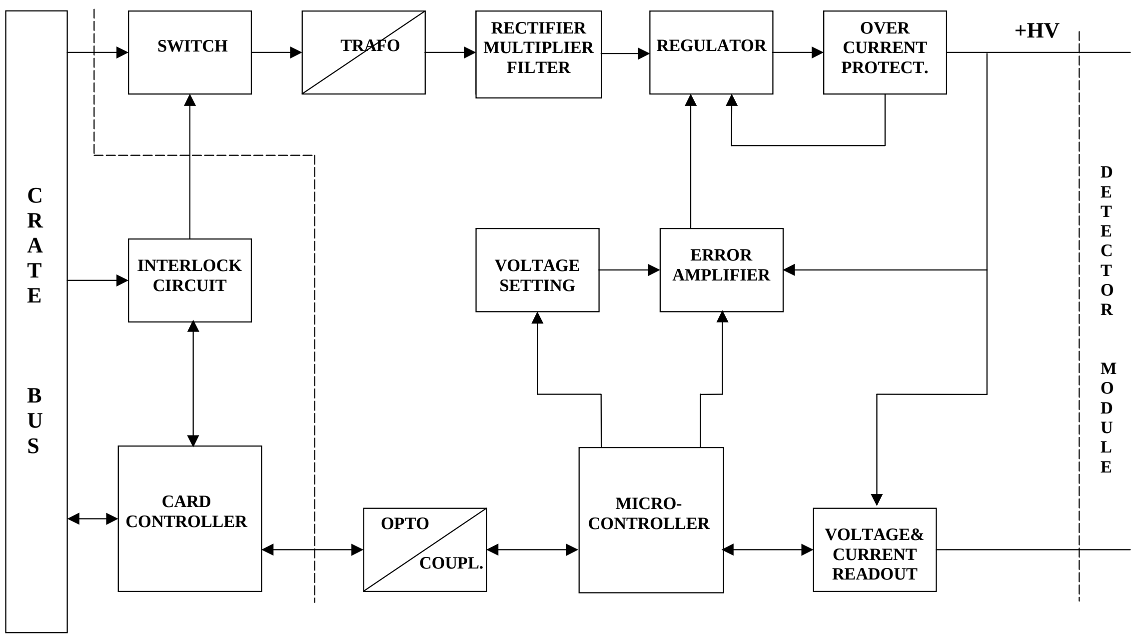

Figure 1. Block diagram of the HV channel

located on each card. In the final version, with the custom backplane and bus, the card address is determined by the card position in the crate. The main advantage of such solution is that all HV cards are identical.

IV. Single Channel Description

The single channel block diagram is shown in Fig. 1. It can be seen that the channel's full isolation is realized by optocouplers in the communication line and by transformer in the supply line.

A. Switch

The micro relay Meisei P12 - controlled by the card processor as well as by the interlock circuit - is used to turn power on or off for the channel's transformer.

B. Trafo

The high frequency transformer (48 kHz, square wave) has one primary winding for U_{0m} of 58 V and three secondary windings of $U_{1m} = 280$ V, $U_{2m} = 12$ V and $U_{3m} = 12$ V. The ferrite core EF16 is made of H21 material by Fonox. U_{2m} and U_{3m} are auxiliary voltages supplying channel's circuitry.

C. Rectifier, multiplier and filter

A typical voltage multiplier (x2) is based on two high speed diodes UF4007 and two capacitors. The high voltage RC filter is applied for a ripple reduction.

D. Regulator

The high voltage MOSFET power transistor BUZ78 of U_{DSMAX} equal 800 V (catalogue value) is used as series regulator.

E. Over-current protection

An absolute (hardware) over-current protection is set to 5.2 mA. If the current exceeds this value the voltage is automatically reduced to keep the current below the limit. This protection is independent on the programmable current trip limit which is described below.

F. Voltage setting

Micro-controller can set the output voltage of the channel to the required value by setting the 10 bit serial DAC. This setting is always controlled via the ramp-up or ramp-down procedure. Ramp-up and ramp-down rates are to be chosen from several preset values. It may happen that the ramp-down rate will be determined by the time constant of the circuit rather than by the controller. Preset values are 10 V/s, 20 V/s, 50 V/s and 100 V/s.

G. Optocouplers

Serial, asynchronous and duplex communication line between card and channel micro-controllers is “broken” by two optocouplers 6N137 operating at 2 Mbaud.

H. Voltage and current readout

The channel micro-controller continuously reads the output voltage and current using 12 bit multichannel ADC. The output voltage is measured with high precision voltage divider. Output current of the channel may vary from tens of nA to 5 mA. Every channel is equipped with the multi-range current readout system. A particular range is selected by the channel micro-controller to keep the readout accuracy high. These ranges are partially overlapping. One measurement cycle of voltage and current takes about 20 ms. The accuracy of the voltage measurements can be estimated from the following algorithm: ±(0.1% of the reading + 2 digits) and similar for the current accuracy: ±(1% of reading + 2 digits), where the significance of a digit is shown in column “resolution” in Table 1 for all ranges.

Table 1. Range and resolution of voltage and current measurements

	RANGE	RESOLUTION
Voltage	512 V	1 dgt=125 mV
Current	41.97 uA	1 dgt=10.24 nA
	209.2 uA	1 dgt=51.07 nA
	1.029 mA	1 dgt=251.4 nA
	5.945 mA	1 dgt=1.451 uA

I. Error amplifier

This block is based on the operational amplifier OP07 with a low input offset voltage. The voltage regulation loop can be open or closed by the micro-controller. When the loop is open then the series regulator is cut off.

III. FUNCTIONS AND COMMUNICATION

A. Functions of the channel controller

Principal functions of the channel controller are:

- serial interface interrupt service which takes care of the transmission/reception of the channel output and input buffers,
- “new settings” command recognition and execution,
- “send status and measurements” command recognition and execution,
- permanent output voltage measurement and check for the over-voltage,
- permanent current measurement and check for the over-current condition.

After recognition of the “new settings” command the channel controller receives 13 bytes: 2 control bytes, 2 bytes of the nominal voltage (binary form of the setting for DAC), 8 bytes of current trip limits (two per each of four probe resistors) and one byte specifying a ramping rate.

The channel controller program drives measurements of the output voltage and current with an endless loop interrupted eventually by the serial port. After completion of the input a new command is recognized and executed. The channel controller transmits status and current measurements only on request from the card controller. The output string consists of one control byte, the byte of status, two bytes of the voltage measurement and two byte of the current measurement.

B. Functions of the card controller

The card controller, for final design, communicates with the crate controller via the parallel port serviced by a custom protocol (for the VME version standard read/write commands are used). Main functions of the card controller are:

- services for interrupts from the serial link, parallel link and timer,
- execution of ON and OFF commands received from the create controller and addressed to a given channel,
- distribution of new settings received from the crate controller and addressed for a given channel,
- regular query of active channels for their status and measurements,
- transmission of the status and measurements of a given channel, on request from the crate controller,
- specific reactions to over-voltage and over-current trips reported by channel controllers (in status).

The card controller updates regularly status and measurements buffers querying sequentially each of active channels i.e. channels for which the ON command has been received and executed. Each buffer is ten bytes long and contains control byte, status, two bytes of voltage and two bytes of current measurements as well as four bytes for control and debug purposes. Bits of the status byte have the following meanings:

- bit 7 - channel tripped for the over-voltage
- bit 6 - channel tripped for the over-current
- bit 5 - channel is switched off for over-voltage
- bit 4 - unstable voltage (e.g. during ramping)
- bit 3 - reserve
- bit 2 - reserve

- bit 1 - MSB of the 2-bit number of the current probe resistor
- bit 0 - LSB of the 2-bit number of the current probe resistor

In the case of the over-current trip an immediate action is taken by the channel itself. The action of the card controller is limited to the status transmission.

In the case of the over-voltage trip the card controller checks whether the output voltage of the channel has dropped to zero as requested by the channel's controller. If not then the channel is switched off and the status bit 5 is set.

References

[1] ATLAS Coll., Specification for ATLAS Silicon Microstrip Detectors for the ATLAS Final Design Review. **ATLAS SCT"/"Detector FDR"/"99-2**, 1999

[2] ATLAS Coll., SCT Bias Voltage Power Supply Specification, Version V2.03. January 2000.

[3] ATLAS Coll., ATLAS Inner Detector Technical Design Report. **CERN/LHCC 97-16, 1997**. European Laboratory of Particle Physics, CH-1211 Geneva 23.