COMPACT PCI/PXI BASED HIGH VOLTAGE CARDS

Sandeep Babel, BiRa Systems, Albuquerque, NM 87107, U.S.A.

Abstract

High voltage power modules find uses in many applications like the Photo multiplier Tubes (PMT), Ionization chambers, CRT systems testing, high voltage biasing for Avalanche Photodiodes, Photo detectors, X-ray tubes, Pulse generators which are used in radars, lasers, EMC testing and other imaging applications. Providing high voltage, to these applications, which can be remotely controlled in a small, confined area, is a problem many laboratories around the world face. The LV and the HV series of high voltage systems present experimenters with voltages ranging from several hundreds upto +/- 5kV in a rugged CompactPCI / PXI chassis, running National Instruments' LabView. The CompactPCI architecture offers modularity, tight integration and low cost. Apart from that, the deterministic and real time nature of the operating system (LabView) also allows these modules to be remotely controlled and monitored over the Ethernet. The high voltage cards can be easily custom tailored to a particular voltage and current requirement [1].

SYSTEM REQUIREMENTS

Physics experiments often require many (up to 1000) continuously variable high voltage (2kV to 6kV), low current, power supplies for various types of experimental apparatus such as photo multipliers, ion chambers, tracking chambers etc. In the past, this has often required a variety of units from different manufacturers with different voltage-current ratings, control interfaces, voltage, current and state monitoring circuitry and output protection features. The physical packaging and I/O connections were also dissimilar. This lack of uniformity caused problems with system implementation, maintainability, and control-monitor software because of the necessity to custom-tailor for each type. The work required to implement large, multi-channel high voltage systems with these system constraints was often difficult and expensive [1].

Traditional High voltage power systems were offered in NIM, VME or CAMAC architecture. To implement a full 64 bit bus in VME, a 6U form factor is required whereas in CompactPCI both 32 bit and 64 bit can be implemented using a 3U form factor. Unlike the older VME based high voltage power systems, where the electronic design constraints were mainly cost, newer designs must meet additional requirements for size, power consumption and remote controlling and monitoring capability. Newer designs should also be able to seamlessly integrate with other manufacturers off the shelf products in an environment containing a large variety of electronic equipments. CompactPCI architecture allows easy integration of the functionalities that are needed into a single system. Instrumentation, data acquisition, machine vision, motion control, and bus interface modules are just a few types of CompactPCI modules available. It also provides a high-performance and a rugged industrial form-factor along with high compute density and higher quality components [1].

Figure 1: Model 4720A HV board produces 0 to -300 Volts in a CompactPCI package

Major system requirements while designing the system were as follows:

- DC supplies should be modular with the modules supplying an array of voltage ranges (typically -100V to -5KV)
- Current draw in a quiescent state should be very less (typically, < 1 mA).
- Individual modules should be stable to 5% of the set value over a period of time.
- The ability to control and monitor the voltage and current characteristics remotely using a computer.
- Small and robust design which is easy to maintain and scalable in nature [1].

SYSTEM ARCHITECTURE

There are three versions of these high voltage module boards. Model 4720 have four high voltage channels each having a voltage range from 0 to -300 volts; Model 4720A has three channels with each channel having a range of 0

1-4244-0917-9/07/$25.00

to -300 volts and Model 4730 has two channels, each having a range of 0 to -5KV. Since robustness and remotely control and monitoring of these high voltage systems were a priority, the selection of an appropriate, modular computer-interface bus system was necessary. CompactPCI proved to be the bus backplane of choice on the basis of above mentioned facts [1][7].

The chassis selected for hosting these High voltage cards is National Instruments™ PXI-1044 which accepts both PXI and CompactPCI 3U modules. The PXI-1044 offers 467 W of available power across 14 slots with 25W of cooling for each slot provided by three fans running at 140 cfm. The chassis is PXI specification Revision 2.1 compliant. It is equipped with NI-8196 which is a high-performance Pentium M 760-based embedded controller for use in PXI and CompactPCI systems. The PXI-8196 include high performance peripheral I/O such as 10/100/1000 Base TX Ethernet, four USB ports, an RS-232 Port and an IEEE 1284 ECP/EPP parallel port. This allows the user to have a choice in selecting the peripheral for remote communications with the chassis. Additionally it comes with 512 MB dual-channel DDR2 RAM and Windows XP Professional already installed on it [1][2].

Figure 2: A CompactPCI/PXI chassis with High voltage boards.

At the heart of the system for control and monitor is Oxford Semiconductor's 32 bit PCI chip running at 33 MHz. The chip is a target only PCI controller, and is fully compliant with PCI 2.2 specifications. [3] The boards also have a CMOS FLASH-based 8-bit microcontroller chip from Microchip™ which acts as a slave, and assists in controlling and monitoring the feedback voltage. The microcontroller features 256 bytes of EEPROM data memory, self programming, a Universal Asynchronous Receiver Transmitter (USART) and a synchronous serial port which can be configured as either 3-wire Serial Peripheral Interface (SPI™) or the 2-wire Inter-Integrated Circuit (I²C™) bus [4].

Model 4720 and 4720A utilizes DC to high voltage DC converters which require an input current of 70mA, with an input impedance of 10K ohm. These modules have less than 10mV peak to peak of ripple and are protected against continuous output short circuit protection. These supplies do not have Input/Output isolation; hence Isolation amplifiers were used to effectively isolate the high voltage. At full running capacity, each of these High voltage modules uses 0.7 Watt of power. On the other hand Model 4730 utilizes DC to high voltage DC converters which require 380mA of input current and supply 3W of output power with a 5% typical regulation. The modules also have a 6KV input/output isolation [1][7].

The finished Model 4720 & 4730 boards have 8 layers with impedance controlled traces and split ground planes for high and low voltages respectively. Special care has been taken, to prevent noise from coupling on to the digital data, address and control lines which interface with the CompactPCI bus. A 3U form factor of these boards present significant challenges for noise coupling, heat dissipation and arcing. When running at full capacity, the 4730 boards produces an amazing 384 volts/inch-sq, this even at low output current has a potential of arcing over the air. The 4730 is a two slot wide 3U form factor board [1].

The High Voltage DC converters output is linearly proportional to the input voltage; hence a scheme was designed, that can be controlled easily by the microcontroller using SPI or I2C bus interfaces. For this purpose, an adjustable micro power Low dropout voltage regulator from National Semiconductor™ [6] is used in conjunction with a SPI compatible 256 position digital potentiometer. By changing the resistance value of the digital potentiometer, the voltage regulator can be set to different output voltages, which can then be fed to the High Voltage DC converter.

The output voltage from the high voltage DC converters , after suitable filtering is brought down to a more manageable range of 0 to 5 volts using a 60:1 voltage divider in the case of 4720 and 4720A and 1000:1 divider in the case of 4730 which is then monitored using 10 bit ADCs. The modules also have the additional facility of monitoring the output current from each module. Low side current monitoring is possible by using AD8202 chip from Analog Devices™ [5]. It has a very high common mode voltage range of -8 to +28V at 5V supply. The output voltage from the High voltage DC converters is passed through appropriate shunt resistors to get a full scale differential voltage of 100mV, which is then increased by a factor of 50 to make it suitable for an ADC input range of 0 to 5V. The boards also use many of Linear Technology's™ Power Management chips to juggle the available power to be used on the board.

1-4244-0917-9/07/$25.00 ©2007 IEEE

To control the power supply cards, LabVIEW from National Instruments™ was chosen because of its easy to understand graphical interface controls. LabVIEW also provides a deterministic, real time performance along with LabVIEW Real Time for data acquisition and control. LabVIEW can be readily deployed and the cards can easily be controlled and monitored over Ethernet.

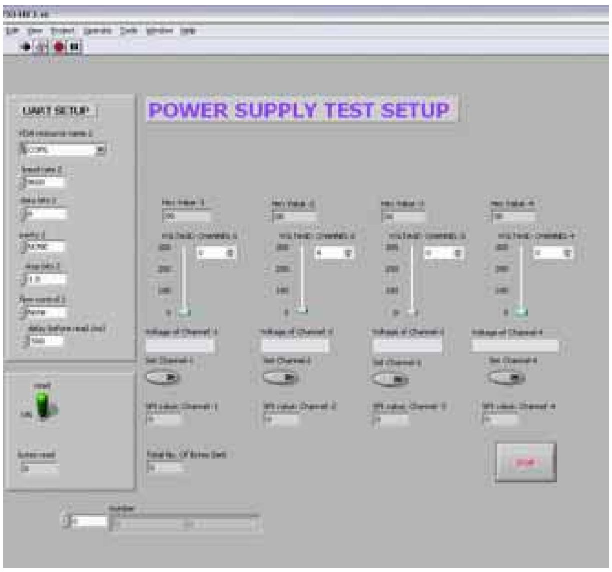

Figure 3: LabView Setup for testing, controlling and monitoring the High Voltage boards.

Intensive computing prowess of today's chip implies that less discrete components need to be used to achieve almost identical results, which results in a drastic reduction of PCB real estate and cost. Apart from that, it is much easier to maintain and scale these systems.

APPLICATIONS

Possible applications of these high voltage power modules will be in Photo multiplier Tubes (PMT), which are used for analytical applications like emission-spectroscopy, fluoroscopy, atomic-absorption-spectroscopy as well as bio and chemo-luminescence. Ionization chambers, CRT systems testing, high voltage biasing for Avalanche Photodiodes and Photo detectors, X-ray tubes, pulse generators which are used in radars, lasers, EMC testing and other imaging applications are other potential users of this technology.[1]

REFERENCES

[1] Sandeep Babel, "High Voltage Strikes CompactPCI" RTC Magazine, October 2006 Issue.

[2] Active Media: http://www.ni.com

[3] Active Media: http://www.oxsemi.com

[4] Active Media: http://www.microchip.com

[5] Active Media: http://www.analog.com

[6] Active Media: http://www.national.com

[7] Active Media: http://www.bira.com

