A CONTROL AND DATA ACQUISITION SYSTEM BASED ON THE PXI BUS FOR THE NEW PHOTON BEAM POSITION MONITOR PROTOTYPE

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Abstract
Usually, in large experimental physics facilities, systems based on the VME bus, are widely used both for the lower level of the control system and for data acquisition. It is common to use this environment also for those applications that do not really need its features. The PXI bus is an industrial extension of the well-known PCI bus used in the desktop computer industry. It may represent a less expensive alternative platform for controlling a complex experimental set-up increasing also the system performances. The development of a new generation of diagnostic detectors at Elettra allows investigating this opportunity. The design of its control and data acquisition system is based on the PXI bus and it is fully described in the paper. The benefits and the inconveniences of this platform are then discussed. Besides real-time applications, based on a commercial DSP board, are also discussed with their integration in the PXI system.

1 INTRODUCTION

An UHV test chamber with a detector prototype to characterise is an ideal environment for testing the portability and the performances of new industrial standard products in the experimental physics world. The aim is to have a compact and rugged system not very expensive but with also real time capability. So, we have built up a complete data acquisition and control system based on the PXI bus from National Instruments. The system provides both low priority tasks as the chamber controls and high performance deterministic data acquisition capability.
A project for the development of a novel photon beam position monitor (PBPM) for the high brilliance beamline of ELETTRA has been used for testing this system [1]. It is very common to have limited experiments or particular measures or tests set-up, which need such a kind of systems.

2 THE SYSTEM SPECIFICATIONS

The new PBPM is based on a system of blades that intercepts the photons and, instead of measuring the photoemitted currents, collects the photoemitted electrons and performs an energy characterisation. After which a calculation of beam position is done [2]. This novel approach to the PBPM requires a more complex mechanical layout and more sophisticated electronics. In order to collect and analyse the photoemitted electrons, we have adopted a technique commonly used for high-resolution electron spectroscopy. An electrostatic energy selector has been chosen as this has the advantage of being more reproducible and faster to vary than a magnetic type. We have designed a custom Electron Energy Analyser (EEA) composed by an input lens set-up and a hemispherical dispersing element. The system may be divided into two parts: an UHV chamber with its controls and the detector with its settings and data acquisition. In fig. 1 is depicted the detector layout.

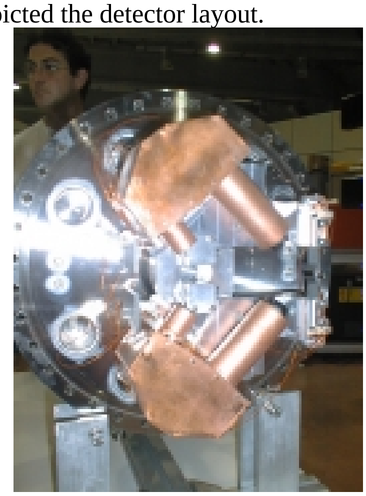

Figure 1: The New PBPM prototype layout.

A three-axis manipulator has to be controlled with great accuracy according with the output of three high precision optical encoders. A link with the Ethernet network has to be assured for acquiring, from the mains control systems, the machine status and the beamline parameters continuously. Besides, the vacuum and the thermal conditions are to be monitored. All these tasks have not strict timing constraints. On the other hand, the detector controls are more critical. First, a high voltage power supply system, which configures this electrostatic device, has to be continuously checked and remotely controlled. Then a multiple mode data acquisition system has to be provided. Two different ways of data acquisition are needed: counting mode and current mode. Each mode has a dedicated electronics: the former detects the fast pulse train coming out from the analyser and counts them. The latter integrates, with a configurable constant time, the signal. Subsequently, in both cases, the data is processed in order to find the vertical beam centre.

3 THE HARDWARE & SOFTWARE PLATFORM

3.1 Host Computer and Operating System

We take into account several considerations for the choice of the HW platform. In particular, we need a flexible and scalable solution within a rugged industrial package suitable for the hard environment of a synchrotron

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radiation facility. The functionality of the system might vary over the time and more devices might be added whenever. Besides, compatibility with the more common software environments is mandatory. Moreover, an affordable price has to combine with the high performances requested for some data acquisition paths. So, a PC-based technology solution has been chosen. Because the PCI bus does not satisfy our requirements, we adopt an extension of the industrial CompactPCI bus: the PXI bus from National Instruments. As operative system, we have chosen Windows NT while for the real time applications an I/O card with a dedicated CPU on board is used. The PXI-1000B mainframe is the physical support for the controller and the I/O boards. It is fully compatible with PXI and CompactPCI modules and it is a compact 3U-sized unit with an 8-slot chassis. The PXI-8156B PXI embedded computer is the high-performance PXI system controller with the entire standard I/O features built in. This computer has on-board PCI video and is still able to connect to the PXI bus without the need of a PCI-to-PCI bridge. Therefore it preserves the full 132 Mbytes/s PCI bandwidth for other PXI boards. In addition, the PXI-8156B supports masters in all seven available PXI slots. The package provides also an USB port, a 10BaseT Ethernet port and an IEEE 488.2 (GPIB) interface.

3.2 The CompactPCI and PXI Buses

The CompactPCI bus combines PCI (Peripheral Component Interface) electrical specifications with Eurocard mechanics and high-performance connectors to define a core architecture that can be used to build various types of industrial systems [3]. Besides the PXI (PCI eXtension for Instrumentation) extends CompactPCI for measurements and automation while it maintains interoperability with ComapctPCI [4]. The PXI specifications are of three kinds: electrical, mechanical and software. The first defines timing and triggering extensions that bring high-performance instrumentation capabilities to CompactPCI systems.

Figure 2: The PXI products from National Instruments.

The second adds requirements for environmental testing, electromagnetic compliance, and safety testing. Active cooling with fans is also required and controller locations are more rigidly defined to improve interoperability. The latter defines minimum software driver requirements that PXI modules must meet for operation in system using Microsoft Windows.

3.3 The I/O Boards

The PXI hardware platform fully supports also any CompactPCI board. Therefore, a great number of I/O boards are available on the market suitable for any kind of data acquisition application. We consider three particular boards that allow us to cover our specifications: the PXI-6030E and the PXI-7030E from National Instruments and the cADC64 from Innovative Integration. The first is a multifunction I/O board with 16 single-ended inputs at 16 bits, 2 analog outputs at 16 bits, 8 TTL digital I/O lines and 2 counters at 24 bits. The second is a stack of two boards: a PXI-6030E and a dedicated CPU card optimised for fast and deterministic I/O acquisition. The DAQ daughter board resides on the embedded PCI bus of the controller board. The RT board communicates to the host computer in which it resides through shared memory on the 7030 processor board. Both the host computer and the embedded processor have access to the shared memory. The memory is allocated for various tasks. For example, LabVIEW RT uses part of the shared memory for downloading software on the board. There is also some memory space allocated to the user for passing data between the host PC and the processor board. Moreover, it is suitable for real-time applications while it maintains the plug-and-play property. This allows an easy application programming without the low-level driver coding. Finally the cADC64 board, from Innovative Integration, supports an on board Texas Instruments DSP and 64 single-ended multiplexed analog inputs [5]. This board needs also a development system for the DSP programming. However, it is suitable for those fast real-time applications that need the direct control of the low level software operations. The development tools available are a C cross-compiler, the assembler and a set of libraries. The DSP is a high performance TMS320C32 32-bit floating-point capable of up to 60MFLOPS/30MIPS. On-chip peripherals include two flexible 32-bit counter/timers, 2 prioritised DMA controllers, a bi-directional sync serial port, 2Kbyte of dual-access SRAM and a prioritised interrupt controller. The analog input chain employs eight 16-bit, instrumentation-grade A/D converters addressable as pairs by the DSP via four memory mapped-locations. Each A/D features an analog input simultaneously sampled upon receipt of a DSP software command or an external TTL trigger. Each of the native analog inputs is routed through a differential instrumentation amplifier into a six-pole (120 dB/decade) anti-alias filter. A simple, high speed, memory-mapped 16-bit latch is available to support general purpose digital I/O. The port may be software or externally clocked at rates to 5 MHz and each bit on the port is capable of sourcing 40 mA.

3.4 The DSP System

The Compact PCI interface supports bus mastering, directed by the DSP, capable of bursts of 132 Mbytes/sec and sustained transfers of 20 Mbytes/sec on most platforms. This provides superior connectivity with transfer rates well above competing 'C32 offerings featuring awkward, register-based interfaces suitable only for object code downloading. Multiple cards may be installed in systems with full driver support under Windows 95 and NT. The cADC64 may be programmed in C or Assembler using the tools available in the development package. The Windows device driver and DDL provided support host PC application development in Visual C or Basic, and any other environment capable of linking to a standard Windows DLL. Alternately, the board is compatible with a number of packages including LabVIEW for users seeking a turnkey data acquisition and analysis solution. Additionally, the Ventura library provides full-bandwidth access to the extensive hardware complement of the cADC64 without any DSP programming.

Figure3: The CompactPCI I/O card, from Innovative Integration, with a TMSC32 DSP on board.

3.5 The Software Tools

The Windows NT operating system allows using several high level programming languages and software tools which are available on the market. An easy start-up of the data acquisition and control system has been implemented in LabVIEW. LabVIEW RT [6] is the particular release that we adopt. This extension allows real-time applications using dedicated boards as PXI-7030E. Moreover the most performance demanding applications have been developed in C and/or Assembler and run on the DSP boards available. Any application may be also written in C (e.g. VisualC) or CVI from National Instruments. Another interesting environment is the Linux OS. In particular the novel LinuxRT may represent an improvement of the conventional Windows OS. The whole HW set-up is fully compatible with a future OS upgrade to LinuxRT. An Unix-like real-time operative system will add further features to this compact embedded control system, like multitasking and multithreads capability, a full determinism of the system and the remote logging and control.

4 A COMPACT CONTROL SYSTEM

The control system main tasks are the following: the manipulator movements, the vacuum and cooling system monitoring, the instrumentation control via GPIB interface and the beamline and machine control systems links via Ethernet. The manipulator permits three movements through stepping motors. The positions are controlled by optical encoders with a precision up 1 µm. Each stepper is driven with digital I/O and its movements are controlled through a closed feedback loop with the optical encoder. The vacuum devices and the cooling system are controlled through serial interfaces. These links provide low speed information on the UHV chamber status. The most critical instrumentation is controlled via IEEE 488.2 parallel interface. A complex system of floating HV power supplies is one of them. It polarises the electrodes of the detector up to some kV with 16-bit accuracy. Another example is the electronics for the data acquisition in counting mode. A 16 channels intelligent system provides the 16-bit counters necessary for the data collection. A local CPU with a real-time OS on board provides a GPIB high level interface for the data transfer to the host. The PXI controller with its on board Ethernet interface allows the connection with the main control systems of Elettra. Besides, the link with the Beamline Control System (BCS) provides bi-directional data flow. The main machine parameters, the beamline status and the remote control of the insertion device may be available by a TCP/IP simple client and server application. The PXI modularity allows a further expansion of the system adding other mainframes for supporting more I/O devices.

5 CONCLUSIONS

A new interesting solution for small and medium size experimental set-up controls has been presented. An innovative HW and SW platform based on standard PC component has been analysed. The performing PCI bus enclosed in an industrial extension system called PXI has been introduced in a harsh experimental physics environment. Flexibility, modularity, reliability and maintainability represent its most interesting features. An implementation of a control and data acquisition system of an experimental apparatus has been realised. The combination of the standard-de-facto low cost Windows or Linux environments and the high level deterministic real-time capability seem to be very attractive for the most demanding experimental physics control system.

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