DEVELOPMENT OF AN EMBEDDED SYSTEM FOR A MULTI-CHANNEL HIGH VOLTAGE CONTROL AND MONITORING IN 1.7MV TANDETRON ACCELERATOR

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Abstract

A 1.7MV tandetron accelerator at Materials Science Group of IGCAR is regularly used for carrying out radiation damage studies, particle irradiation based materials research. A dual beam irradiation facility is being setup which uses heavy ion beam from the 1.7MV Tandetron accelerator through the 30^0 beam line and helium ion beam from a 400 kV accelerator. In the beam line, a set of beam handling devices such as quadrupole focus lens and electrostatic steerers with +/-30kV and +/-10kV power supplies are used to focus and steer the ion beam. A PIC16F877A microcontroller (UC) based embedded system has been developed to facilitate remote control and monitoring of these power supplies from the control PC of the tandetron accelerator, resulting in improved focusing and fine tuning of the ion beam. The prototype of the embedded system was designed, developed, tested and installed in the beam line. The system works satisfactorily and is under regular use. Working principle, design details, salient features of the embedded system are discussed in the paper.

INTRODUCTION

Particle Accelerators and Ion implanters play an important role in the field of materials research in a wide ranging applications from doping of semiconductors to simulation of neutron damage in materials. At Materials Science Group, IGCAR, a dual beam irradiation facility is being setup to investigate the void-swelling behaviour of reactor structural materials such as D9,ODS alloys at elevated temperatures from 300K-1027K. This setup uses heavy ion beam like Ni or Au from the 1.7MV Tandetron accelerator through the 30^0 beam line and helium ion beam from a 400 kV accelerator. To obtain a well focussed ion beam with small spot size, a set of beam handling devices such as quadrupole focus lens and electrostatic steerers with +/-30kV and +/-10kV power supplies are used in the UHV beamline of 1.7MV tandetron accelerator.

The existing PC based accelerator control system of the accelerator supplied by M/s HVEE is fully customised and hence could not support the control and monitor of additional beam line components like quadrupole focus lens and electrostatic steerers in the 30^0 beam line. Further the M/s Glassman make power supplies used for energising the triplet lens and steerers were not equipped with standard PC communication feature to enable PC based remote control and monitoring. These posed difficulties in focusing and fine tuning of the ion beam. To address this problem, we have designed, developed and installed a simple low cost multichannel remote control cum monitor system based on the popular PIC16F877A microcontroller(UC).

EMBEDDED SYSTEM

Figure.1 shows the block diagram representation of the embedded system. The embedded system is centered around the popular PIC16F877A, a 8-bit high performance FLASH microcontroller from the Microchip® PIC family. This CMOS based RISC microcontroller has been chosen after taking into account of its price, performance and rich peripheral set as well as the availability and ease of use of software development tools. Internal Flash program memory guarantees fast and easy re-programmability.

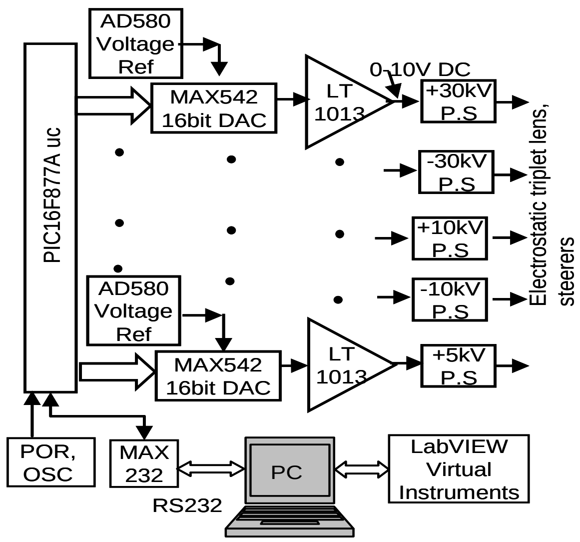

Figure 1: PIC16F877A Embedded System –multichannel remote control part.

Hardware Design

The hardware design for the embedded system is mainly divided into three sections 1) remote controlling the power supply output 2) remote monitoring the output of the power supply 3) bidrectional communication with the host PC. For remote controlling the power supply output, and monitoring it, analog remote programming and monitoring feature of the power supply is used. The analog remote programming involves a highly stable and adjustable 0-10VDC programming voltage for each of the five power supplies. As shown in figure.1, the UC generates control voltages in the range 0-10V DC on 5 independent channels. Each channel consists of a 16 bit DAC MAX542, a stable voltage reference AD580 , high precision op amp LT1013 and low temp coefficient metal film resistors. Using 3-wire communication, the microcontroller sets the output of the DAC based on the set value received from the host PC. The DAC output after necessary amplification and buffering by LT1013 is converted into 0-10V and fed to the power supply, thus setting the desired output.

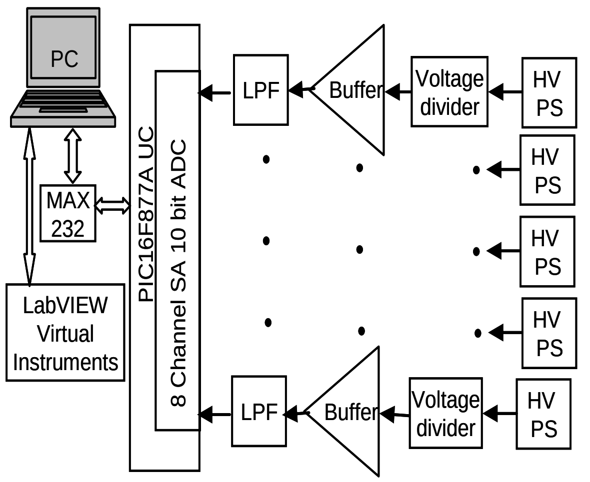

Figure 2: Remote monitoring part of the embedded system.

For remote monitoring the power supply output, as shown in figure.2, the design exploits a 0-10V DC monitor output available with each power supply. These signals, after necessary signal conditioning, are digitized using a 10 bit SAR ADC built-in in the UC and sent to the control console PC through full duplex RS232 communication. Since very low level signals in the range of few tens of uV are involved in the design, careful attention was paid in low noise circuit design, component selection, PCB layout design with good grounding and stable power supplies.

The UC offers several distinct protocols all based on its UART peripherals for connecting to a host PC. We have implemented hardware based bi-directional RS232 protocol, which is the most commonly used protocol, for interfacing the embedded system to the control PC. Necessary TTL to RS232 and vice-versa level conversion is achieved through the MAX232 level converter.

Software Development

We have developed two distinct layers of application software for the embedded system: the microcontroller firmware application and the host PC application. The microcontroller firmware, "multichhvcontrol.c", was written in ANSI C using a PCWH C compiler from Custom Computer Services, USA . This complier includes an assembler, a C compiler, a linker and a series of debugging tools that allow easy development of applications. The program developed controls all the functions and user interfaces of the embedded system and runs on the PIC internal program memory. The program is structured into various modules for carrying out different tasks: intialisation or setting up of ADC, digital I/O, interrupts, bi-directional hardware RS232, receipt and decoding of control commands from the host PC, acquisition and sending of latest contents of the ADC to the host PC, etc. The program is very compact and occupies only 14% of 8K FLASH ROM program and 20% of 368bytes RAM memory available with PIC16F877. So expansion of the program for inclusion of additional functions in future can easily be met, given the large size program and RAM memory of the microcontroller.

We have developed a virtual instrument based application program, "multichhvcontmon.vi", for running on the host PC side. The virtual instrument was developed using a powerful Graphical programming language, Laboratory Virtual Instrument Engineering Workbench(LabVIEW) from National Instruments, for multiple reasons like easy to develop, debug and maintain, excellent windows based graphical user interface, better flexibility, portability among different PC platforms, support of variety of hardware from IEE488 to USB, a comprehensive library for data collection, presentation and storage, etc. The virtual instrument, consisting of several stand alone executable sub VIs such as serialportinitialise.vi, serialwrite.vi, serialread.vi, stringmanipulate.vi, etc, has been developed to provide a user interactive graphical interface for the embedded system. This interface enables the user to adjust and set the bias voltages and monitor the output of the power supplies. It also helps to graphically monitor instantaneous ion beam current, accumulated charge counts. Because of the inherent modularity of labVIEW programs, we can easily add functionalities like on-line monitoring of parameters, file storage, etc.

Tests and Results

The embedded system was tested thoroughly and performance at component and module level were observed. Programming and monitoring stages, virtual instruments are found working as per our requirements. The programming voltages generated were found to have 13 bit setting resolution, better than 2% accuracy, high stability and low temperature drift. After observing satisfactory performance, the embedded system is put into regular use.

REFERENCES

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