NEW CONTROL SYSTEM FOR THE SPES OFF-LINE LABORATORY AT LNL-INFN USING EPICS IOCS BASED ON THE RASPBERRY PI

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Abstract

SPES (Selective Production of Exotic Species) is an ISOL (Isotope Separation On-Line) type RIB (Radioactive Ion Beam) facility under construction at the LNL-INFN (Italy) dedicated to the production of neutron-rich radioactive nuclei by uranium fission. The project adopted EPICS as general frame for the control system. An off-line laboratory has been developed to study the test bench of the ISOL target front-end and the related controls. With the perspective to test new solutions for the control system components, the implementation of a new EPICS IOC developed at LNL was developed and studied.

The IOCs are based on the low cost computer board Raspberry Pi with custom-made expansion boards. The expansion boards consist on multi-channel 16bits ADCs and DACs, digital inputs and outputs and stepper motor drivers. The operating system is a modified version of Debian Linux running EPICS soft-IOCs.

This development allows to check the flexibility of this solution with the goal to have a distributed control system based on customized IOC for controlling the instrumentation devices as well as to read the information from the field using the EPICS channel access as communication protocol. This solution is expected to be very cost effective and easy to customize.

INTRODUCTION

SPES (Selective Production of Exotic Species) is an ISOL [1] type Radioactive Ion Beam (RIB) facility for the production of neutron-rich radioactive nuclei by uranium fission. The RIBs will be produced by proton-induced fission on an UCx multi foil direct target [2] at a rate of 10^{13} fps, more than one order of magnitude larger than the currently available beam intensities.

At LNL (Laboratori Nazionali di Legnaro) in Italy, although the construction of the new facility for the project (Figure 1 shows its layouts) has been recently started, an off-line laboratory has been under operation for the past four years. In this laboratory, the SPES target front-end apparatus (Figure 2) has been tested. In particular, it has been a test bench for new instrumentation, detectors and control systems.

From an early stage of the project, EPICS (Experimental Physics and Industrial Control System) was chosen as the standard framework for developing the control system. In this sense, a variety of EPICS IOCs (Input/Output Controllers) have been used on the control system of the off-line front-end [3].

In this current work, it is presented the use of a new kind of IOC developed at LNL. It is based on the computer board Raspberry Pi with custom-made expansion boards. These IOCs represent a flexible, easy to adapt, low cost and open solution for the control system.

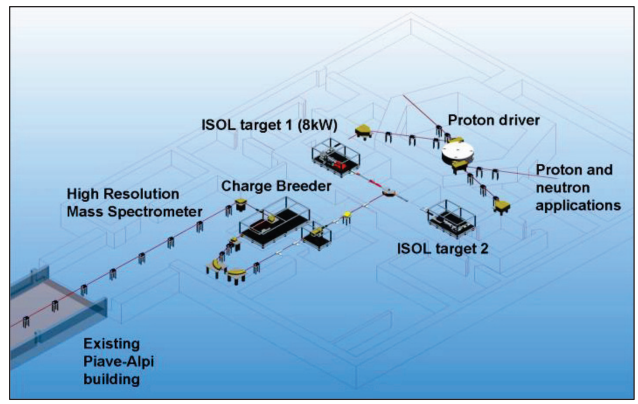

Figure 1: The SPES facility layout.

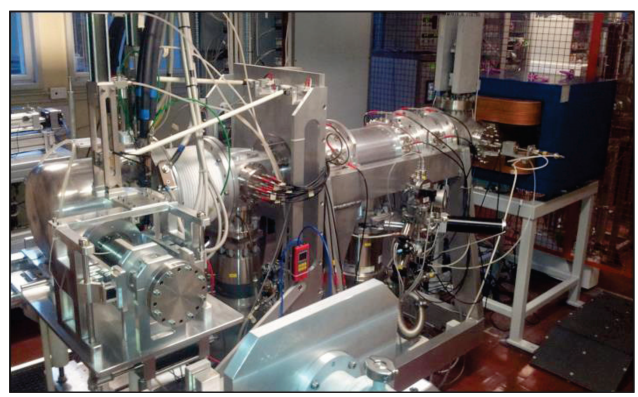

Figure 2: The SPES off-line front-end laboratory at Legnaro.

THE NEW EPICS IOCS DEVICES

The core of the IOC is the computer board Raspberry Pi (Model B, rev. 2) (Figure 3). This computer board uses the Broadcom BCM2835 SoC (System on a Chip) which contains an ARM1176JZFS, with floating point, running at 700 Mhz (although in most of our applications it was overclocked to 900 Mhz), and a Videocore 4 GPU. It has 512 MB of RAM, two USB 2.0 ports, one Ethernet port, and one low-level peripheral GPIO (General Purpose Input/Output) port, among others. It boots a modified version of Debian Linux running the EPICS soft-IOCs from an external SD card, which also acts as long-term storage. The board is powered with 5 VDC and consumes around 3.5 W.

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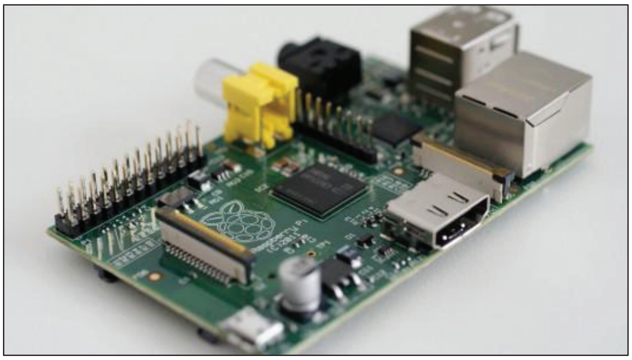

Figure 3: Raspberry Pi computer board (model B, rev. 2).

In order to provide data acquisition and instrumentation control capabilities to this board, tailored home-made expansion boards where developed. Diverse kinds of boards have been developed at LNL for specify applications. For example, a board with a logarithmic current-to-voltage converter combined with an ADC was used for acquiring the signal from a faraday cup; or a board with a series of DACs was used for controlling power supplies with analog interfaces. In general, the expansion boards have analog inputs and/or outputs (using ADCs and DACs with a resolution of 16 bits), digital inputs and/or outputs (using digital I/O expanders) and/or stepper motor drivers (using microcontrollers). These boards were connecter to the Raspberry Pi using its GPIO port.

In addition, for applications where several serial port (UART RS232 or RS485) were necessary, commercial serial-to-USB converter were used. In the same way, commercial ethernet-to-USB converters allowed to expand the number of ethernet interfaces where needed. In these cases, using commercial adapter was cheaper and less time consuming that developing similar expansion boards. Furthermore, the added ports are treated by the operation system as local ones, so, no additional coding is necessary for their use.

The operating system is a modify version of Debian Linux, called Raspbian OS. EPICS (version R3.14.12.3) was compiled and installed on this system. Asyn driver (version 4.20) and StreamDevice (version 2.6) where appended to the EPICS installation for some applications. The control systems were developed as EPICS soft-IOCs running on the systems.

In order to communicate with the home-made expansion board, a program written on C, running on the same system acts an interface for the soft-IOC. This program performs two functions: on one hand, it uses the Broadcom BCM2835 C library to access the GPIO port in order to write and read data to/from the expansion boards. On the other hand, using the EPICS Channel Access (CA) C library, it reads and writes this data from/to EPICS interface records on the soft-IOCs running locally on the device (see Figure 4). Inside the IOC, these interface records are processes according to the control algorithm.

The graphical user interface was developed using the EPICS CA client CSS (Control System Studio). This user interface is execute on a remote personal computer, connected to the EPICS CA. Figure 5 shows as an example a screen of the user interface.

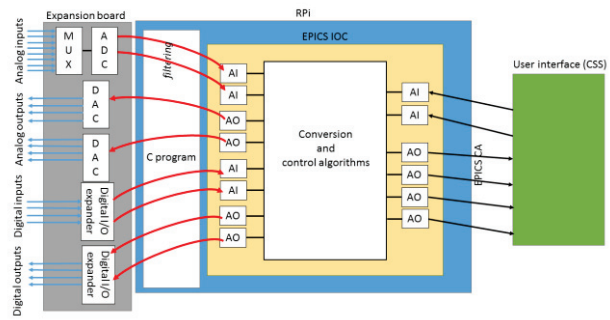

Figure 4: Interface between the EPICS IOC records and the expansion board using a C program.

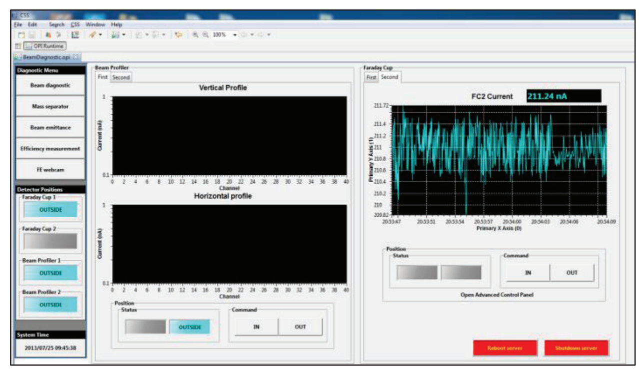

Figure 5: Screen of the user interface.

IMPLEMENTATION OF THE IOCS IN THE OFF-LINE LABORATORY

Several systems of the front-end apparatus are currently controlled using the new IOCs. For each kind of instrument or detector device, a tailored IOC is used. All the IOCs form a distributed control system using the EPICS Channel Access as communication protocol.

The principal characteristics of each IOC application will be describe next.

Beam Diagnostic Data Acquisition

The standard beam diagnostic unit of the SPES project consists on a faraday cup for the beam current measurement and a beam profiler meter. Two of these system are currently installed on the off-line laboratory.

The faraday cup output is an analog current signal, while for the beam profiler it is a vector of 80 current signals. Both instrument positioning systems are controlled using stepper motors.

The IOC implemented for these application uses three kind of expansion board: one single channel ADC with a current-to-voltage converter (for the faraday cup signal), two 40 channel ADC with 40 current-to-voltage converters (for the beam profiler signals), and two stepper motor driver (for the positioning of both instruments).

Figure 6 shows a picture of the IOC for this application.

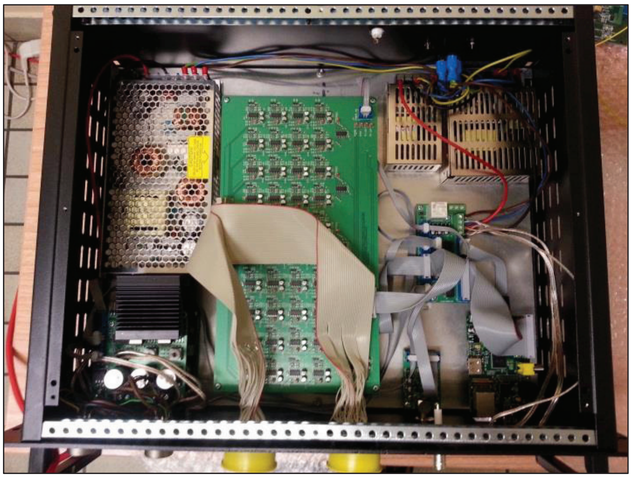

Figure 6: EPICS IOC for the control of the beam diagnostic unit.

Mass Separator

The mass separator uses a magnetic and an electric field for filtering the beam ions according to their mass. The magnetic field is generated with an electromagnetic coil driven by a high current power supply. On the other hand, the electric field it is generated with an electrostatic dipole driven by two high voltage power supplies. Furthermore, the magnetic field is measured using a hall effect probe. The power supplies and the probe measurement instrument have a serial port (UART RS232) as communication interface for the control system.

The IOC implemented for these application uses a quad serial-to-USB converter (USB-COM485-PLUS4 from FTDI Chip) to communicates with all these instruments.

Moreover, a series of temperature sensors (DS1822 from Maxim) were installed on the water cooling circuit and coil. They are read by the IOC directly though the GPIO port using the 1-Wire communication protocol.

Figure 7 shows a picture of the IOC for this application.

Focalization System

For the focalization of the beam in the front-end, there are use a series of electrostatic steers and electrostatic quadrupoles. These elements are driven using high voltage power supplies, which are controlled using voltage analog signals for the output setting and digital signals as interlocks.

The IOC implemented for these application uses an expansion boards with a series of 16 bit DACs (for setting) and ADCs (for feedback) and digital I/O expander (for interlocks).

Figure 8 shows a picture of the IOC for this application.

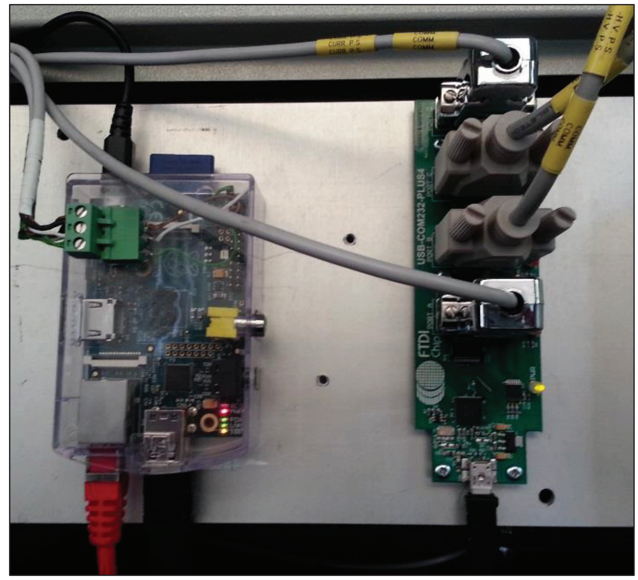

Figure 7: EPICS IOC for the control of the mass separator.

Figure 8: EPICS IOC for the control of the focalization system.

FUTURE IMPLEMENTATIONS OF THE IOCS IN THE OFF-LINE LABORATORY

Currently, there are under implementation new IOCs for controlling other system of the front-end apparatus. The principal characteristics of each IOC application will be describe next.

Beam Emittance Meter

The beam emittance meter uses two 80 wire grid detectors which output is a vector of current signals. The positioning of the detector is controlled using two stepper motors and two linear potentiometers.

The IOC currently under implementation for these application will use almost the same kind of expansion boards used for the beam diagnostic unit IOC, that is: four 40 channel ADC with 40 current-to-voltage converters for both grid detector signals, two single channel ADC for the acquiring the potentiometer signals, and two stepper motor driver for the positioning of the detectors.

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Vacuum Instrumentation Data Acquisition

The vacuum measurement instrument installed on the front-end have a serial port (UART RS232) for configuration and data acquisition.

The IOC currently under implementation for these application will use the same quad serial-to-USB converter (USB-COM485-PLUS4 from FTDI Chip) used for the mass separator IOC for acquire the vacuum measurements and change the setting on the instruments.

PLC-EPICS Communication Interface

In the off-line laboratory, two PLC (BMXP342020 from the Schneider Electrics Modicon M340 family) are in charge of the control of the vacuum system and the safety control system [4].

The IOC currently under implementation for these application will act as a bridge between the PLC network and the EPICS network. It will use an ethernet-to-USB converter (DUB-E100 from D-Link) for adding a second ethernet interface to the IOC. In this way, one ethernet interface will be connected to the PLC network while the other will be connected to the EPICS network. The IOC will implement a home-made MODBUS-TCP driver that reads some variables of the PLCs and writes them onto EPICS records on the IOC.

CONCLUSION

It was presented a new kind of EPICS IOC and it use on the SPES off-line laboratory at LNL. The IOCs are based on the low-cost computer board Raspberry Pi in combination with standard USB converter and tailored home-made expansion board.

The current implementation of these IOCs into the control system of the off-line laboratory shows that these IOCs can be very flexible and easy to adapt and customize, allowing their use in a large number of diverse applications. Furthermore, as could be seen on the plans for the new implementations, most of the expansion board can be reutilized in different systems.

Due to the simplicity of the expansion boards, the fact that they can be reutilized on different applications, and above all the low-cost of the Raspberry Pi as core of the system make this solution very cost effective.

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