Nuclear Inst. and Methods in Physics Research, A 890 (2018) 96–101

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

24-channel dual microcontroller-based voltage controller for ion optics remote control

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ARTICLE INFO

Keywords:
Voltage control
Ion optics
Electron affinity
Microcontroller
Firmware

ABSTRACT

The design of a 24-channel voltage control instrument for Wenzel Elektronik N1130 NIM modules is described. This instrument is remote controlled from a LabVIEW GUI on a host Windows computer and is intended for ion optics control in electron affinity measurements on negative ions at the CERN-ISOLDE facility. Each channel has a resolution of 12 bits and has a normally distributed noise with a standard deviation of <1 mV. The instrument is designed as a standard 2-unit NIM module where the electronic hardware consists of a printed circuit board with two asynchronously operating microcontrollers.

1. Introduction

Atomic and ionic spectroscopy studies depend on advanced, accurate and versatile measurement and control instruments. This includes vacuum systems, ion sources, ion optics, lasers and laser optics, particle detectors and data acquisition electronics (hardware and software) [1].

This work describes the design of the hardware and software of a versatile, multi-channel, remote controlled ion-optics controller used in laser-detachment experiments (of isotope shift studies of negative ions) at the CERN-ISOLDE radioactive beam facility. To this end, a collinear laser-negative ion beam apparatus has been designed [2,3] which has so far successively determined the electron affinity of negative ions of tungsten [2,4], platinum [5] and chlorine [6]. The objective of the new GANDALPH apparatus (Gothenburg ANion Detector for Affinity measurements by Laser PHotodetachment) developed at CERN is to extend these studies to isotope shifts in negative ions of heavier radioactive elements such as astatine and polonium [7]. These elements are of great interest since they are potential radio-therapeutic agents for targeted alpha therapy in nuclear medicine [8]. This has already been demonstrated for iodine [9]. Fig. 1 illustrates a simplified diagram of the experimental set-up.

In the interaction chamber, the negative ion beam and the laser beam are collinear and the laser wavelength is tuned in order to find the exact photon energy at which the electron affinity process occurs [10]. Two opposing laser beams are used in order to cancel the Doppler shift bias [11]. In the detection end, remaining negative ions are deflected into a Faraday cup [12] and neutralized atoms will be unaffected by this field and instead impact on a In_2O_3:Sn coated glass plate and release secondary electrons from the surface. This electron current is detected by a Channel Electron Multiplier [13] and serves as an indicator of the electron affinity process.

Fig. 1 also illustrates the ample occurrence of ion optic components and high-voltage deflector plates used to guide the negative ion and electron beams; there are deflector plates, ion lenses (1D and 3D) and collimator plates, all controlled by precision tunable, high-voltage, low noise Wentzel power supplies in standard NIM modules (Nuclear Instrument Modules) [14]. They can be locally controlled but has also a front panel analog input for remote control; the conversion ratio is 1 kV/V.

The objective of this work was to create a 24-channel voltage output instrument where each channel outputs a 0–5 V DC voltage (with millivolt resolution) that can be individually remote controlled from a host PC and connected to the control input of the Wenzel high-voltage power supplies via miniature LEMO connectors. The voltage resolution needs to be approximately 1 mV or better. The instrument should be enclosed in a standard (2 unit) NIM module (68 mm). Fig. 2 illustrates the front panel layout. For convenience, a 2 × 8 character alpha numeric display and a 24-notch turning knob are added; this facilitates a local readout of each channel voltage. The module is connected to a host Windows computer via an RS232-to-USB FTDI cable (on the back panel).

On the host PC, a Graphical User Interface (GUI) was developed in LabVIEW.

A related work has previously been reported; Piyadin et al. [15] designed an 8-channel module for control of Wenzel N1130 high-voltage supplies in 2017. This system was also based on 12-bit DACs and used 14-bit ADCs to monitor the supply outputs and the system was controlled from a host computer via a CAMAC bus (Computer-Aided Measurement and Control). The work presented here does not require a CAMAC crate

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https://doi.org/10.1016/j.nima.2018.02.035
Received 3 January 2018; Received in revised form 31 January 2018; Accepted 6 February 2018

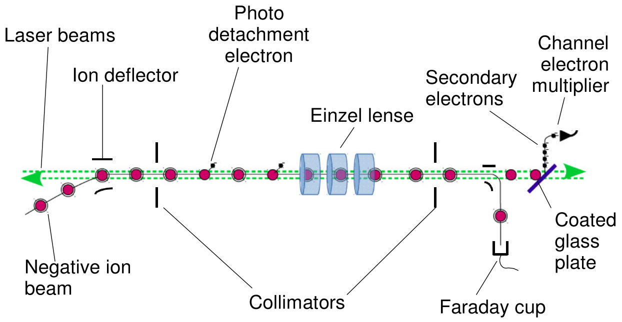

Fig. 1. Experimental setup.

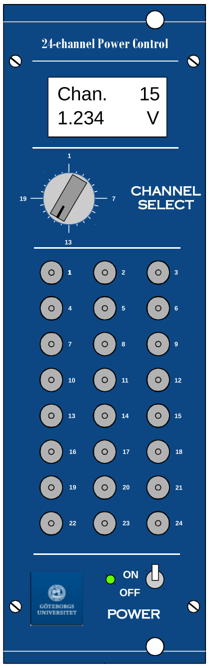

Fig. 2. Front panel of NIM instrument.

(only a standard USB port) and has three times as many channels. It also fits into a standard NIM module but can also be used as a stand-alone desktop instrument (since it has a separate power supply). Since the hardware is based on two independent microcontrollers, this instrument is also very versatile because the performance depends on firmware that is easily upgraded (via in-circuit programmable interfaces on the back panel).

2. Method and material

2.1. Hardware

Fig. 3 illustrates a schematic diagram of the dual microcontroller design. The printed circuit board (pcb) houses two 8-bit PIC microcontrollers from Microchip [16,17] that operate asynchronously and independent of each other.

To the PIC16F1709 controller are three 8-channel, 12-bit DA converters from Linear Technology [18] connected via an SPI serial interface; this is how the 24 control voltages for the ion optics are generated. The PIC16F1709 controller receives commands from the host PC (via an asynchronous RS-232 interface, using an USB-to-RS232 FTDI cable) and the controller decodes this command into a channel number and a voltage and then imparts this voltage to the right DAC slave. The

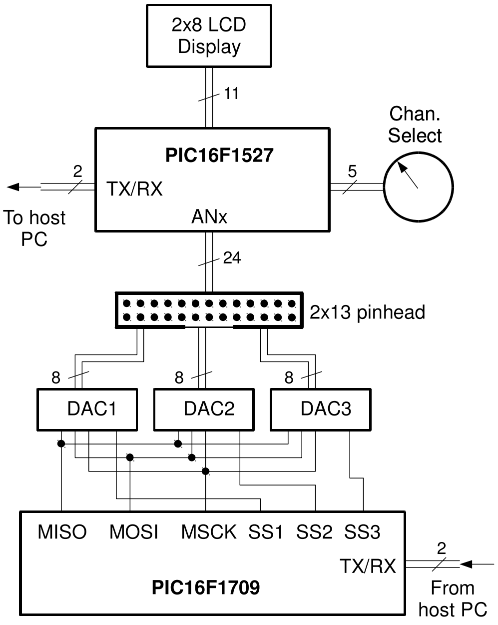

Fig. 3. Dual microcontroller ion optics controller.

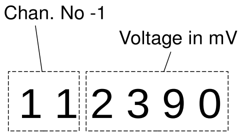

Fig. 4. The command syntax.

DAC channels are not buffered; the Wenzel N1130 power supplies have control inputs that require a modicum of load current; <50 μA [14]. The 24 single-ended voltages are transferred to the 50 Ω miniature LEMO female coax connectors on the front panel via a 2 × 13 pinheader.

The PIC16F1527 controller has 28 analog channels of which 24 are used to monitor the DAC outputs [16]. A 24-notch, turning knob on the front panel is used to select which one of the channel voltages that is displayed on the front panel LCD display. The intrinsic ADC on the PIC controller has 10-bits resolution only, which indicates that the voltages are measured with two bits less resolution than the voltage resolution on the DACs' output. This is not a significant deficiency since the panel display is only an auxiliary readout, but a firmware remedy is discussed (and implemented) in Section 2.3 below.

Fig. 3 also indicates that the PIC16F1527 transfers data to the host PC; it broadcasts the channel voltages periodically and this can optionally be read by the host PC in order to compare the requested voltage with the actual voltage.

2.2. Firmware: PIC16F1709

The PIC16F1709 receives the voltage and channel commands from the LabVIEW GUI on the host PC. If the user wants to set a voltage of, say 2.390 V on channel 12, the GUI will send six ASCII characters to the PIC16F1709 via the asynchronous serial interface, see Fig. 4. (In software, channels are numbered from 0 to 23.)

A great effort has been invested into making this communication robust; the firmware must not fail if the received data does not conform to the format above. Verifying that the channel number and the voltage are within the allowed ranges is simple enough, but handling (accidental/incidental) variations in data length is somewhat harder. To that end, a few global variables have been utilized to "reset" the command