

USB-BASED RADIATION MONITOR

by

Vujo DRNDAREVIĆ¹, Nenad JEVTIĆ¹, and Radivoje DJURIĆ²

Received on July 10, 2006; accepted in revised form on August 3, 2006

The Universal Serial Bus has become a dominant interface for the connection of standard peripheral devices to a PC computer. This paper analyzes the possibilities of USB bus applications in the field of measurement and environmental monitoring. As a result, a gamma radiation monitor consisting of an USB-based universal peripheral device and a gamma probe with a GM counter, has been designed. For the interfacing monitor with the powerful and easy to use LabVIEW software package, an instrument driver as a set of virtual instruments has been developed. The proposed monitor is a flexible instrument which can be used for laboratory measurements, as an environmental radiation monitor or for training purposes. Connected to the laptop computer, the monitor becomes a portable instrument suitable for field measurements. Basic measurements and functionality properties of the radiation monitor are presented here.

Key words: radiation monitor, USB bus, gamma ray, GM tube, LabVIEW

INTRODUCTION

Computer measurement systems traditionally consisted of standalone devices, connected to the computer via the serial RS-232 or IEEE-488 bus. With the advance of PC-based measurement technology, the measurement devices were connected to the PC via an ISA or PCI common bus [1]. An example of such a solution of a gamma radiation monitor has been described in ref. [2]. Direct connection with the PC via ISA or PCI plug-in cards caused compatibility problems and the connecting procedure itself had to be done by experts. This paper analyzes the possibilities of applying a modern Universal Serial Bus (USB) for connecting measurement and monitoring equipment to the computer.

The USB bus was initially designed to connect peripheral devices such as a keyboard or a scanner to a PC. In the last few years, the USB has been widely adopted. All new PCs and laptops are equipped with USB ports and most modern operating systems support it. The USB has, *de facto*, become a low-cost PC interface standard for consumer applications. Only very recently has it, also, become a popular interface for measurement and control applications. A more detailed description of USB characteristics and communication protocols of the USB bus are shown in ref. [3].

Numerous limitations related to the connection of peripheral devices to personal computers were eliminated by using the USB interface. Such as the limitations of PC functions due to the limited number of free slots on the mother-board or a limited number of standard communication interfaces, for example. Up to 127 peripheral devices can be connected to a PC by using USB hubs. Easy connection of peripheral units is in accordance with the *Plug and Play* concept, due to the hot-plug capability which allows adding new peripheral devices, or their removal, without powering down the computer. The device is plugged into a PC and then recognized by it. After the first installation of appropriate software, the device will always be recognized by the host PC. The power supply of devices with a relatively low consumption is possible via the USB bus itself. The standard USB 2.0 enables a data transfer

Technical paper

UDC: 681.538:539.166

BIBLID: 1451-3994, 21 (2006), 2, pp. 73-78

Authors' addresses:

¹ Faculty for Transport
Telecommunication Department
305, Vojvode Stepe, Belgrade, Serbia

² Faculty for Electrical Engineering
Electronics Department
73, Bul. Kralja Aleksandra, Belgrade, Serbia

E-mail address of corresponding author:
vujod@EUnet.yu (V. Drndarević)

rate of 480 Mb/s, which is more than $4 \cdot 10^3$ times higher than the fastest transfer rate achieved by the serial RS-232 interface.

We have designed and implemented a practical solution for a USB-based radiation monitor, as described in this paper. The monitor is made of a universal peripheral device and a gamma probe. The gamma probe is connected to the universal peripheral device which is, in turn, connected to the computer by the USB bus. The peripheral device and the gamma probe are described in the following chapters, along with the essential functionality and measuring characteristics. In addition to connecting the gamma probe, the universal peripheral device may also be used for connecting different sensors with a PC. It has inputs for analogue and digital signals and pulses. This enables the connection of sensors for physical, chemical, and biological environmental measurements.

The authors have, primarily, concentrated on developing and providing relevant software. The software driver was developed in the form of a set of virtual instruments (VI) as an interface with the LabVIEW software package. The processing of signals or data acquired by these devices, as well as graphical user interface, is performed by LabVIEW software. The combination of the USB data acquisition hardware with the capabilities of LabVIEW software, represents a very powerful measuring instrument for laboratory experiments and fixed monitoring systems. This enables the user to create a specific application for his measuring or monitoring systems in a graphical environment, quickly and efficiently.

Since it is PC-based, the monitor is a bench type instrument, highly suitable for use as an element of a computer network for environmental or area monitoring. Connected to the laptop computer, the monitor becomes a portable instrument suitable for field measurements. If a high sensitivity detector is applied, this PC-based unit can be used to monitor people and vehicles in transit.

UNIVERSAL PERIPHERAL DEVICE

The peripheral unit connected to the PC by the USB interface is designed as an universal input-output peripheral device. Various measurement sensors can be connected to it. This enabled us to enhance the possibilities of measuring a higher number of environmental parameters on a specific location and achieve simple improvements of the measuring functions of the system. The block diagram and the appearance of the USB peripheral device are shown in fig. 1.

The pulses from the gamma probe are transmitted to the input for pulse counting (CNT, fig.

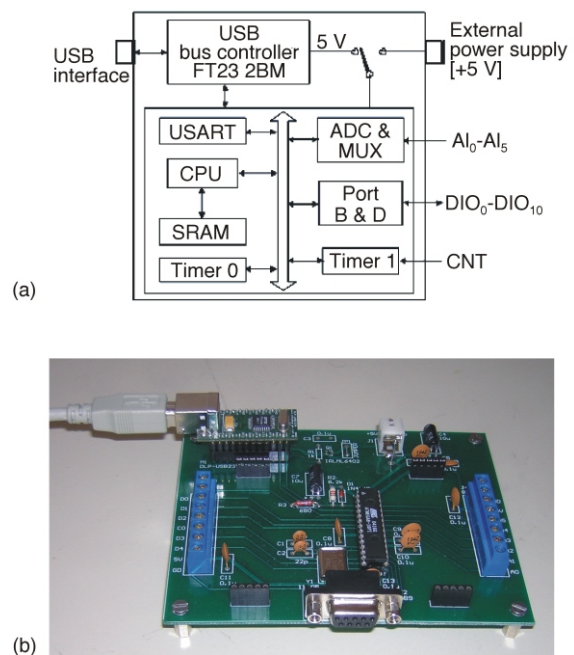


Figure 1. Block diagram (a) and appearance (b) of the USB-based, universal IO device

1a). The power supply of +5 V for the gamma probe is achieved through the universal peripheral device. In addition to the counting input, the USB-based universal peripheral device also enables connecting 6 analog input signals and 11 digital input-output signals. This device was made by using a microcontroller ATmega8 [4] and a USB bus controller, FT232BM [5]. The communication between the FT232BM and ATmega8 was accomplished by means of an asynchronous serial interface. The microcontroller used included an integrated analog-to-digital converter and a serial interface which enabled the implementation of simpler hardware for the peripheral device.

As shown in fig. 1, separate controller is responsible for communication via USB bus, in this case FT232BT. The ATmega8 microcontroller is used for acquisition of signals from the sensor or measuring devices, as well as for data processing. These two controllers communicate by a serial connection. The mentioned approach in the implementation of USB-based peripheral devices provides maximum utilization of controller resources needed for measurement-control functions. According to the USB protocol, the USB bus controller is, in fact, the one factor in charge of the communication between a peripheral device and a PC. The application of the USB bus controller makes the development of application software of a personal computer much easier, largely due to the fact that the USB controller is frequently supplied with an adequate driver by the manufacturer.

Application software communicates with the USB peripherals by calling the relevant driver functions. These functions initialize the peripheral device and transfer blocks of data via the USB bus. All driver functions are placed in the respective DLL (Dynamic Link Library).

The acquisition of analog signals is done by using a 10-bit AD converter and a six-channel multiplexer. These signals are taken to inputs AI_0 - AI_5 . The sampling rate of the measurement is defined by the software, periodical setting of the conversion start and the reading of results. The maximum sampling rate per channel is $5 \cdot 10^3$ samples per second. This sampling rate is sufficient for application to most measuring and control systems.

The digital input-output lines DIO_0 - DIO_{10} are connected to ports B and D of the micro controller. Each digital line of the acquisition module can be either an input or an output line. The selection of data direction is performed on the level of software application.

A 16-bit timer of the microcontroller is used for the implementation of the counter, enabling processing signals to have a frequency not higher than 500 kHz. The signals for counting are fed to the input CNT. This input is used for connecting to the radiation detection probe. The description of the probe design is given in the following chapter.

GAMMA PROBE DESIGN

If a gamma radiation sensor is added to the USB-based universal peripheral device described in the previous chapter, then this device connected to the PC can be used as a very flexible tool for environmental radiation monitoring. Connecting a higher number of computers equipped with such radiation monitors into a computer network, would result in an economically feasible network for environmental radiation monitoring.

The gamma probe consists of a GM counter and a high voltage power supply. A block diagram and the appearance of the radiation probe are shown in fig. 2. The probe was designed by using the ZP1200 Philips GM tube. This very popular, relatively cheap and reliable detector, does suffer from some shortcomings: relatively low sensitivity of $3.5 \text{ s}^{-1} \mu\text{Gy}^{-1} \text{ h}^{-1}$ (^{137}Cs) and an energy dependent response. The first shortcoming has been eliminated by applying a suitable measurement algorithm, resulting in background measurements with a statistical error as low as 1%. The sensitivity of the GM tube within the energy band of 60 keV-2 MeV, varies from +500% to -25%, in respect to ^{137}Cs (662 keV). By introducing a compensating shield, this dependence has been reduced to $\pm 25\%$.

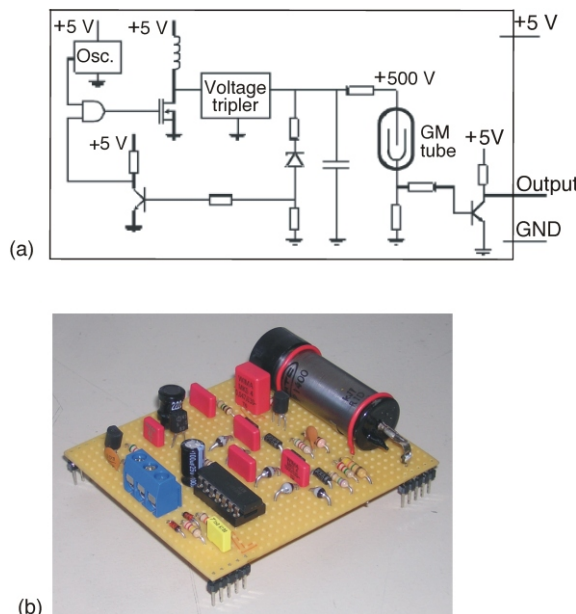


Figure 2. Circuit block diagram (a) and the appearance (b) of the GM probe

The probe is powered by +5 V obtained from the PC through the USB bus. This voltage is converted to +500 V voltage required by the GM tube by a dc-dc converter within the probe. The high voltage is obtained by a suitable combination of a boost converter and a voltage multiplier. Special attention was devoted to the devices with limited power consumption powered by the USB bus. We have implemented a high voltage power supply which consumes only 0.2 mA when the detector is in the background.

Special attention has been paid to the evaluation of the performance of the detector in question when overloaded. The detector has been exposed to gamma dose rates significantly exceeding its measuring range. It has been observed that, for dose rates in excess of 100 mGy h^{-1} , the detector preserved pulse operating mode and a constant count rate of approximately $2 \cdot 10^4 \text{ s}^{-1}$. The detector remained in the pulse operating mode even at the highest dose rate of 30 Gy h^{-1} , made available for these experiments. Although dose rates higher than 100 mGy h^{-1} should prove impossible to be measured by this detector, it is important that it retained the pulse operating mode and that a complete failure of the probe did not occur.

The processed signals are transferred from the probe to the counting input CNT of the micro-controller, located in the universal IO device. The task of the microcontroller is to count the arriving pulses during a certain time interval and to transfer this data to the application software through the USB interface upon the demand of the PC.

SOFTWARE

Software has a predominant role in computer-based measuring systems. For this reason, special attention should be paid to the development of adequate software. We have chosen the LabVIEW for the application of, which allows for an interactive system design by means of a graphical, block-structured, non-procedural language.

LabVIEW is a powerful software package that can be used to design user interfaces for the interactive control of systems in a graphical environment, by taking advantage of its many programming tools and by creating virtual instruments that mirror traditional electronic ones. This software package has world wide acceptance and presence nowadays. It can be found in most research laboratories and in numerous research and development facilities in private businesses. It provides a quick and easy access to instrumentation control and a very large database of drivers for DAQ cards, various computer interfaces (GPIB, serial *etc.*) and instrument drivers.

Each LabVIEW program consists of a Front Panel interface consisting of controls and data fields and a Block Diagram, where the real programming flow takes place. Although it is a graphical programming language, its versatility enables an easy incorporation of modules written in other languages (C, Basic *etc.*) into it [6].

In applying this concept, the crucial step is to implement a software driver for a specific hardware peripheral device. The instrumentation driver represents a software interface between radiation monitor hardware and a high level application program installed on the PC [7]. It consists of a set of LabVIEW virtual instruments. Having the instrumentation driver at his disposal, the user is exempt from low level programming which demands detailed knowledge of hardware device functioning and the protocol for communicating with the USB device. The users can, thus, devote themselves to the development of application software and the implementation of measuring-control functions. We have developed an adequate instrumentation driver for connecting the radiation monitor hardware with the LabVIEW software.

The procedure for the implementation of the instrumentation driver for an USB-based peripheral device starts with the creation of virtual instruments that serve for the calling of the DLL functions for communication with the controller of the USB bus. The manufacturer of the USB bus controller offered a relevant Windows dynamic link library, d2xx.dll, which was applied in this work, as an interface between the driver and the application software [8]. Some of the basic functions included in the dynamic link library d2xx.dll are shown in tab. 1.

Table 1. Basic functions of the d2xx.dll library

Function	Description
FT_List Devices	Information about the devices on the bus
FT_Open	Establishment of connection to the device
FT_Reset Device	Reset of the device
FT_Write	Transfer of data to the device
FT_Read	Reading of data from the device
FT_Close	Interruption of the connection with the device

The access to the dynamic link library is achieved by the built-in function *Call Library Function Node* as shown in the LabVIEW block diagram. The connection of the desired driver function is realized by adjusting the name and the dynamic link library path, as well as the name and parameters of the function. An example of connecting the driver function for sending a series of bytes to the output port of the peripheral device is shown in fig. 3.

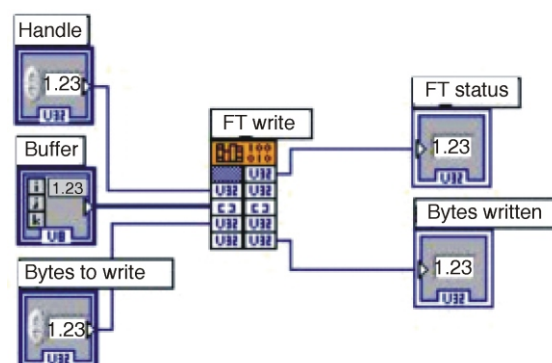


Figure 3. Function Call of the FT_Write from the dynamic link library

The USB instrumentation driver of the peripheral device includes a set of virtual instruments, each performing a specific task. Figure 4 presents a

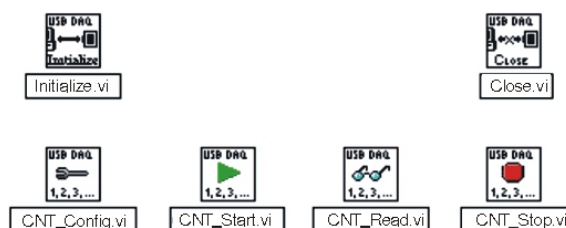


Figure 4. Functions of the instrumentation driver for pulse counting

Figure 5a. Block diagram of the LabVIEW program for a radiation monitor

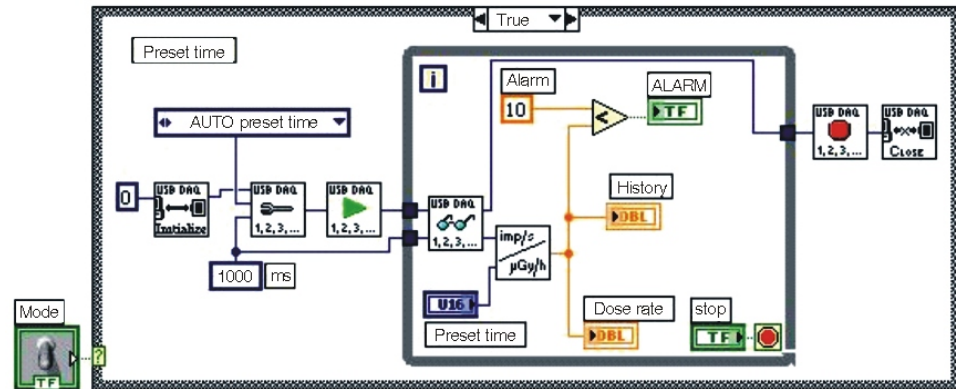
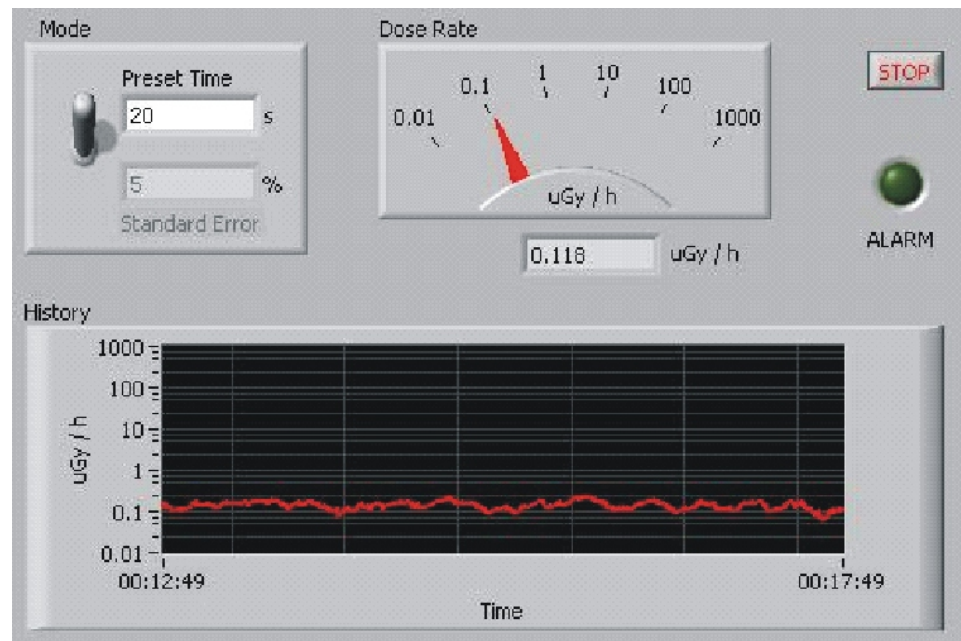


Figure 5b. Radiation monitor front panel



series of virtual instruments which are responsible for the control of the microcontroller counter. These VI configure, start counting, read the results, stop counting and stop the connection with the peripheral device. Similar sets of programming modules are completed for analog input lines and digital input-output lines. Virtual instruments *Initialize* and *Close*, intended for installing and interrupting the connection with the USB device, are common for all the functions of the device.

By connecting particular modules of the instrumentation driver, the user completes his specific application program. Figure 5 shows a simple example of the application program for pulse counting within a preset time-interval which calculates the mean counting rate, performs the conversion of the counting rate into radiation dose rate and shows the result on the digital display and analog panel meter (fig. 5b).

The program implemented in the form of a block diagram shown in fig. 5a plays, in fact, the

role of a simple radiation monitor. The front panel of the monitor is shown in fig. 5b. The measured value of the exposure dose rate is presented in analog and digital form and, also, recorded as a time chart. The new measured quantity is displayed every second. The display can be operated in two modes, providing measurement within a preset time interval or until a predetermined statistical error limit is reached. If the measured dose rate exceeds the predetermined threshold, the alarm will signal it.

CONCLUSION

The USB bus is increasingly gaining favor as an alternative interface for data acquisition and measurement. Computer peripherals such as a printer, scanner, and digital cameras already use USB as a quick and easy technique for connection to a PC. The USB connection simplifies the installation of peripherals by eliminating the necessity to

open the PC to install a plug-in board. For measurement applications, the USB data acquisition modules offer a number of significant advantages.

In this paper, we proposed a USB-based radiation monitor. The monitor consists of an universal peripheral device and a gamma ray probe. A GM counter is used as a gamma radiation sensor. The monitor can be used for measuring dose rates in the range from natural background to 10 mGy h^{-1} . The GM counter transfer function can be linearized by introducing a correction for the counter dead time, so that the measuring rate of the detector can be extended to about 100 mGy h^{-1} . By applying a suitable measurement algorithm, it is possible to measure the natural background with a statistical error in order of magnitude of 5%. In addition to the gamma ray detector, other sensors for environmental monitoring could be connected to the – USB-based universal peripheral device. In such a way, a cost-effective solution for physical, chemical, and biological measurements is achieved. Being computer based, the radiation monitor architecture provides a seamless integration into the Web. The LabVIEW software package can be used for this purpose as well. In fact, Web monitoring with the LabVIEW Web Server was implemented after LabVIEW 6.0 was released. Now version 7.1 has been released and it has even better remote access features. Starting with the 6.0 version, any application can be published as a web file rather easily, using a built-in Web Server. It emphasizes the advantages of the Web for environmental monitoring. If equipped with a high sensitive detector, this computer-based unit can be used for monitoring people and vehicles in transit.

The users of the USB radiation monitor would need a PC with Pentium-class processor and either USB-1.0 or USB-2.0 interface, Windows 98 Second Edition or more recent versions of the Windows operating system.

ACKNOWLEDGEMENTS

The work was carried out within Project No. 6137, financially supported by the Serbian Ministry of Science.

The authors are grateful to Miss Nada Marinković for the fruitful discussions.

REFERENCES

- [1] Samardžić, B., Drndarević, V., Architecture of the Modern Accelerator Control System (in Serbian), *Nuklearna tehnologija*, 15 (2000), 1-2, pp. 42-46
- [2] Drndarević, V., Bolić, M., Spasojević, S., Samardžić, B., A PC-Based Radiation Monitor, *Instruments and Experimental Techniques*, 42 (1999), 1, pp. 103-106
- [3] ***, Universal Serial Bus Specifications, Revision 2.0, April 2006, www.usb.org
- [4] ***, Atmel, ATmega8 datasheet, www.atmel.com
- [5] ***, FTDI, FT232BM USB UART datasheet, www.ftdichip.com
- [6] Jamal, R., Graphical Object-Oriented Programming with LabVIEW, *Nuclear Instruments and Methods in Physics Research, A* 352 (1994), pp. 438-441
- [7] ***, LabVIEW Instrument Driver Standards, Application Note 111, www.ni.com
- [8] ***, FTDI, d2xx Programmer's Guide, www.ftdichip.com

Вујо ДРНДАРЕВИЋ, Ненад ЈЕВТИЋ, Радивоје ЂУРИЋ

МОНИТОР ЗРАЧЕЊА НА БАЗИ USB МАГИСТРАЛЕ

Универзална серијска магистрала (USB) постала је доминантан интерфејс за повезивање стандардних периферних уређаја са персоналним рачунаром. У овом раду анализирани су могућности примене USB магистрале у области мерења и мониторинга околине. Резултат ових анализа је једно решење монитора гама зрачења који се састоји од USB базиране универзалне периферне јединице и сонде гама зрачења са GM бројачем. Посебна пажња поклоњена је развоју софтвера монитора. Развијен је скуп инструментационих драјвера у форми виртуелних инструмената за повезивање са LabVIEW програмским пакетом. Предложени монитор представља флексибилан инструмент који се може користити за лабораторијски рад, као монитор зрачења околине или у образовне сврхе. Повезан са лап-топ рачунаром, монитор представља преносни инструмент погодан за мерења на терену. У раду су дате основне мерне и функционалне карактеристике монитора зрачења.

Кључне речи: монитор зрачења, USB магистрала, гама зрачење, GM бројач, LabVIEW