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USB interface for Medipix2 pixel device enabling energy and position-sensitive detection of heavy charged particles

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Abstract

We have designed an interface board between the Medipix2 single photon counting chip and Universal Serial Bus (USB), which is presently the most widespread PC interface. All necessary detector support is integrated into one compact system ($80 \times 50 \times 20\,\mathrm{mm}^3$) including the detector bias source (up to 100 V). Power supply is internally derived from the voltage provided by the USB connection, so no external device is required. This solution allows to achieve maximum portability of the measurement setup. One of the most significant advantages is the support of back-side pulse processing. The charge generated by an ionizing particle is measured in the bias circuit and can be used for spectroscopic purposes or for triggering. With the present design, the energy resolution of such spectrometry is about 44 keV.The interface board has been designed for connection with present chip-boards carrying one or four Medipix2 chips.

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1. Introduction

Medipix2 is the second generation of a single photon counting ASIC chip developed in the frame of the Medipix Collaboration [1]. The hybrid silicon pixel detector device Medipix2 consists of a sensor chip with 256×256 square pixels of 55 μm size each and a read out chip containing an amplifier, two discriminators and a 13-bit counter for each pixel. Settings of the pulse height discriminators determine the input energy window. The counter is incremented only in case that the energy of the interacting particle falls within the preset energy window [2].

Several read out interfaces have been already developed by members of the Medipix collaboration. The MUROS2 read out board [3] is an FPGA-based interface which is flexible and fast (about 100 Mbit/s) and gives the possibility of performing all kinds of operations on the chip. The MPRS parallel readout [4] uses the chip parallel port to shorten the readout time (up to 512 Mbits/s). A parallel port and another Universal Serial Bus (USB) interface were designed [5]. They are quite simple but rather slow (about 1 Mbit/s in case of USB).

The disadvantage of the above-mentioned Medipix2 interfaces is that all of them require additional support devices for their operation (additional PC data acquisition cards, external power supplies, etc.). Our aim was to develop a fully independent interface which integrates the entire necessary detector support including bias voltage power supply into one compact device.

2. The USB-based Medipix2 interface [6]

The architecture of USB [7] is more than suitable to fulfill all our requirements. It is designed as Plug & Play and Hot-swap. This means that USB devices can be connected to the PC without restarting the computer and they are detected automatically. Another advantage of the USB architecture is that the bus provides not only the communication lines but also the power line (5 V, up to 500 mA).

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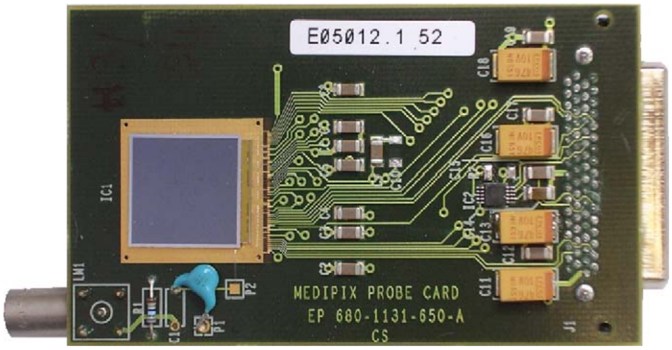

Fig. 1. The Medipix2 chip bump-bonded to the 300 μm silicon sensor carried by a common widely spread chipboard. Chip dimensions are $16 \times 14\,\mathrm{mm}^2$, chipboard dimensions are $79 \times 47\,\mathrm{mm}^2$.

As the Medipix2 chips are supplied mounted on a several types of PCB boards (chipboards), the USB interface was designed to be used with the all current chipboards (see example in Fig. 1).

2.1. Hardware design

A block diagram (see Fig. 2) of the interface board can be divided into several function blocks.

The USB interface block composed of FT245BM chip [8] takes care of the USB management and converts the serial stream into 8-bit wide CMOS data.

After the conversion, the data are used by the ADuC841 MicroConverter® with integrated high speed 420 ksps 12-bit ADC and DAC [9]. This device controls the functionality of the entire interface.

Communication with the Medipix2 chip is enabled via serial line logic converters from LVDS[1] to CMOS logic.

The block of power supplies consists of a 2.2 V power supply for Medipix2 chip and a variable voltage source for Medipix2 detector bias MAX1932 (from 5 to 100 V). For a 2.2 V power supply, the DC–DC step-down regulator is used to reduce the current drawn from the USB host controller.

All interface components are mounted on a four layer PCB[2]. Use of SMD[3] packaged components results in small dimensions of the board ($75 \times 46\,\mathrm{mm}^2$).

All the I/O connectors are situated on the right side of the interface board (see Fig. 3). The left side of the PCB is adapted to be plugged directly to the VHDCI[4] female connector used on all current Medipix2 chipboards. This cable-eliminating solution guarantees a high stability connection (no voltage drops in the power connections).

[1]LVDS stands for Low Voltage Differential Signaling.
[2]PCB stands for Printed Circuit Board.
[3]SMD stands for Surface Mount Device.
[4]VHDCI stands for Very High Density Cable Interconnect.

2.2. Firmware structure

The entire interface is driven by a one-chip microcontroller. The software in the microcontroller has a simple structure described in Fig. 4.

After initialization procedures, the program jumps into the main endless loop and waits for command received via USB. When a command is received it is compared with the table of known commands. If the command is recognized the specific operation is performed. If the command is not recognized an unknown command error message is sent to the host PC. In both cases the program jumps back into the main endless loop.

Owing to this simple organization, new commands can be easily added to the structure without any modifications of previous software.

3. Back-side pulse processing feature

An additional significant advantage of the USB interface is the support of back-side pulse processing. This feature enables the possibility to determine not only the position but also the energy of interacting charged particles.

Each particle of ionizing radiation interacting in the depleted region of the Medipix2 sensor produces a specific number of electron–hole pairs. The amount of charge is proportional to the energy of the interacting particle. Under the influence of an electric field the charge moves to the sensor electrodes creating a current pulse in the bias power supply circuit. If the total charge is large enough, this current pulse can be measured by a charge sensitive preamplifier and, after shaping, be sampled by ADC. This is the case of energetic heavy charged particles (e.g. alpha particles).

The preamplifier board is fabricated separately and it is connected to the interface as a plug-in module (see Fig. 5). This solution separates the analog and digital sections of the device and it allows the assembly of additional shielding of the sensitive analog part.

The energy resolution for back-side pulse alpha particle spectrometry with the Medipix2 detector and the proposed USB interface was determined as about 44 keV at 5.5 MeV in terms of FWHM (Fig. 6).

The maximum count rate of the back-side pulse processing is given by the currently used charge sensitive preamplifier. The total pulse length is 50 μs. Therefore, the maximum count rate is about 20 k counts per second. The pulse is sampled by 420 ksps 12-bit ADC which enables to evaluate potential pile-up effects.

Considering the level of miniaturization reached in the interface, the results are remarkable and satisfactory. Moreover, results can be improved further by better processing of the sampled data (currently only the sampled pulse maximum is used for the spectrum generation).