Short communication

The Multi Unit Activity analyzer: a Windows™ based hardware–software system for low cost, high speed analog to digital data conversion, data acquisition and window discrimination

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Abstract

The Multi Unit Activity analyzer is a hardware–software package for multi-purpose, two-channel data acquisition, with a computer dependent maximal digitizing frequency selectable from 1 to 27000 s⁻¹ on both channels simultaneously. The hardware is connected to an IBM compatible PC through one of the serial ports (standard RS 232 interface). Software was developed to view digitized signals and record or read them on or from the harddisk. The program can also perform amplitude based window discrimination on the raw signal, on-line or during replay. The system is used for recording and analyzing multi unit activity from neuronal tissue in our electrophysiology lab but it can be applied in a variety of other settings. Basic programming routines are available that allow customized data acquisition. © 1998 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Multi unit activity; Analog to digital data conversion; Data acquisition; Window discrimination; Electrophysiology

The Texas Instruments TLC549 LinCMOS 8-bit analog to digital converter was used as the basic component in the hardware. This converter is commercially available as an 8-pin dual-in-line integrated circuit. A PC standard RS 232 serial interface has three control registers that can be used for output (RTS, TxD and DTR) and four that allow input (CTS, DSR, RI and DCD). By maximally exploiting these registers, a total of

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four TLC549 AD converters can be controlled. In order to optimize for speed, each of the two input channels is sampled by two converters. During the conversion cycle (20 µs) of one set of ICs, serial output of the previous conversion cycle from the other set of ICs is performed and vice versa. As can be computed from the duration of the AD conversion cycles, the theoretical maximal digitizing frequency is 50 000 s⁻¹ and per channel. However, a Pentium 133 MHz PC requires ~37 µs to perform one 8-bit serial reading from the TLC 549, so the practical maximal digitizing frequency is ~27 000 s⁻¹ per channel. The actual maximal digitizing frequency depends entirely on the PC to which the hardware is connected. The analog input range of the TLC 549 IC is 0 to ±6 V. In order to be able to process bipolar signals, the hardware includes a dual inverting summation amplifier which lifts the input signal ~3 V and is adjustable under program control with trimmers for both channels. Consequently, an input range from −3 to +3 V is obtained. The inverting summation amplifier can be bypassed by a switch so that the input range from 0 to ±6 can be maintained. The input range is digitized to values from 0 to 255; therefore, the sensitivity of our equipment is 23.4 mV. The device was built on a single sided printed circuit board, which was put in a metal housing measuring 18 × 13 × 6 cm. The inputs are two BNC connectors and the device is linked to the PC's serial port by a standard 25 PIN connector. A layout of the printed circuit board along with the component list and building instructions is available from the authors free of charge.

The software was written in Modula-2, a system programming language derived from Pascal and Modula. The software was developed using the Stony Brook Modula-2 integrated development environment (Stony Brook Modula-2, version 3.0, Stony Brook Software, Thousand Oaks, CA). This Modula-2 package complies with the ISO Modula-2 specification (ISO/IEC 10514-1) and allows development of 16-bit as well as 32-bit applications both for DOS and Windows. The Multi Unit Activity analyzer (named after the original purpose of the software) is a Windows based program which is preferably used under Windows 95 on a Pentium processor, although a Windows 3.1 version is available and a 386 processor is acceptable if high digitizing frequencies are not required. The system was designed to operate as a digital recorder with the PC's hard disk as storage medium. The program has three major modules: one for recording, one for playback and one for analysis which can be used during recording or playback. The actual digitizing frequency is always the maximal possible for a given PC. At lower frequencies (user selectable down to 1 s⁻¹), averages of blocks of data are calculated to obtain the number of digitized values corresponding with the selected digitizing frequency. If a frequency higher than the possible maximal is selected, the maximal is applied and an indicator in the program's toolbar changes from green to red. If data is viewed during the digitizing process, the maximal frequency is much lower (~1 000 s⁻¹ for a 133 MHz Pentium processor). In this case the speed also depends on the quality of the video card. A buffer in RAM memory is filled with digitized data until at least 1 s has elapsed. This buffer is then truncated so that it corresponds to exactly 1 s. This information is subsequently written to the hard disk. Since this takes some time, the data acquisition is not completely continuous. Analyzing the data during recording does not affect the digitizing frequency but takes place between the reading of two consecutive buffers. This makes the gaps in acquisition continuity somewhat larger. On different 133 MHz Pentiums, the total delay time, or gap between reading of two 1 s buffers, varies from 28 to 96 ms when all options (saving raw data, analyzing and saving discrimination data) are selected. The differences depend on speed and access time parameters of the hard disks. When the program is used with only the option 'Save Raw Data' selected, with all other options off, this time gap is <14 ms. Note that at a digitizing frequency of 25 000 per second, a recording of both channels during 1 h consumes ~170 Mb disk space. During playback, the viewing speed is selectable and the original digitizing frequency is displayed in the toolbar. There is a slider to go to a chosen section of the recording (1 s discrimination). Window discrimination implies the counting of the
number of times the amplitude of the signal peaks between two given, selectable levels over a preset period of time. The MUA analyzer allows two discrimination levels in the positive range and two in the negative range for each channel. These can all be set independently. The integration period is adjustable. The discrimination process can be viewed in a separate window showing scaled line graphs indicating the number of discriminations per level per channel per preset time unit. The result of the analysis can also be recorded on the harddisk in a text file (delimited ASCII) which can be imported in spreadsheet programs (e.g. Excel). Selected sections of raw signal data can also be exported as text files for further analysis or printing.