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IBM PC Based Visual Evoked Potential Stimulator and Averager

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Summary

Custom made hard and software enhancement of an IBM PC is described which makes it possible to: i) provide patterned visual stimulation by using the EGA or higher level display, ii) average recorded potentials and iii) monitor the experiment simultaneously. The description is illustrated by examples from a study of retinal evoked potentials in the rat.

Key words

Patterned visual stimulation – Visual evoked potentials – Averaging – IBM PC – I/O board

Introduction

The computing power of contemporary personal computers enhanced by special I/O hardware, makes it possible to accomplish a number of different functions concomitantly to implement complex recording and controlling systems suitable for clinical and laboratory applications. The described IBM PC based set-up designed for study of potentials evoked by visual pattern stimulation and detected by averaging of recorded potentials represents an example of the above system. The system is equipped with an EGA display controller and a custom made I/O board. The software driven stimulation uses the standard display while repetitive stimulus presentation, amplification of the recorded potentials, their A-D conversion and computer interfacing were made possible using a custom made I/O board with a software, i.e. flag controlled data transfer.

Method

a) Pattern stimulation

The advantage of patterned visual stimuli is that the light flux remains constant, so that only the pattern change is responsible for the evoked potential (Holländer *et al.* 1984, Maffei and Fiorentini 1981). These checkerboard or stripe stimulus patterns are usually generated by a tachistoscope or by a CRT display. The tachistoscope provides very good control of stimulus presentation, but it is rather expensive. A raster display, the screen phosphorus of which has low inertia, can be used for the purpose.

Each stimulus represents an exchange of the white and black area of the displayed pattern. There are two ways of presenting patterned visual stimuli by the raster display. A single stimulus pattern might be stored in the video RAM (V-RAM) of the display controller and displayed on the screen and the stimulus alternation is achieved by changing the colour attributes of this pattern (white and black) by a single instruction, i.e. by changing the look-up table of colours applied. The other solution stores both patterns on separate pages of the V-RAM and the displayed pages are exchanged by a single instruction as well. We have used the latter approach. The capacity of the V-RAM of the display controller and the required resolution of the screen determine the number of display pages (i.e. parts of V-RAM corresponding to a single screen) available (e.g. with the maximum capacity of the EGA V-RAM of 256KB there are 8 pages with the resolution of 320x200 pixels or two pages with the resolution of 640x350 pixels).

When the field of vision of the experimental subject is restricted to a part of the screen (window 1), e.g. by a nontransparent cone, then the rest of the screen (window 2) can be used for monitoring the experiment, i.e. for presentation of the current evoked response, averaged waveform, number of responses, etc. The additional information can be displayed regardless of the method of the visual stimulus display, i.e. page switching or attribute changing.

b) Hardware

The storage and processing (averaging) of recorded potentials require that the IBM PC hardware is enhanced by an analog input board. This board can either be one of the universal, commercially available types (Data Acquisition Catalog and Reference Guide 1992), or it can be custom made. We have chosen the latter approach not only because of its cost-effectiveness but also because this solution made the necessary analog amplifier a part of the board and thus to minimized the number of external components of the system. The board consists of: i) an analog amplifier; ii) an A-D converter with synchronization circuitry and iii) IBM PC bus interface.

i) The on-board amplifier is an operational amplifier type TLO72 fed from the IBM PC power supply (±12V). The gain and the frequency band of the amplifier are set by the hardware to $2x10^4$ and to 1-100 Hz (3dB), respectively. The onboard amplifier is connected by a long shielded cable with a symmetrical preamplifier, (gain = 20, input impedance = 100 MOhm, output common mode rejection ratio (CMRR) >100 dB; frequency band (3 dB)= 0-1 kHz) which serves as an impedance transformer for electrodes placed on the experimental subject. A schema of the board and of the related parts of the system is shown in Fig 1.

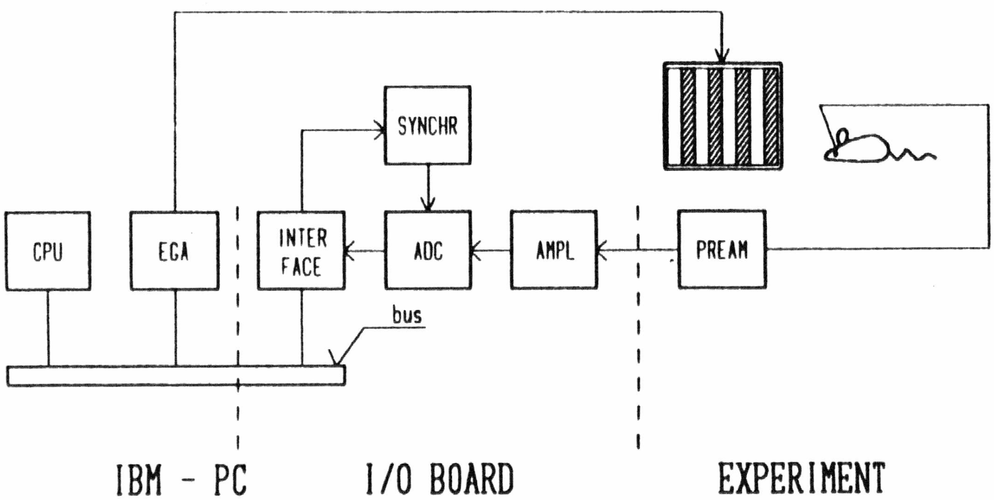

Fig. 1
Schematic diagram of the described system (ADC = A-D converter; Ampl. = amplifier; Interface = IBM PC bus interface; EGA = Extended Graphic Adapter; Pream. = preamplifier; Synchr. = synchronization and timing circuitry).

ii) The A-D conversion is accomplished by a 10 bit ADC type TDC 1013 with 1 μs conversion time. The ADC is controlled by a programmable timer which consists of a fixed frequency clock (20 KHz) and a programmable counter (Intel I-8253). The signal "DONE" of the ADC marks the termination of A-D conversion and simultaneously sets the flag (status latch) which in turn controls the beginning of the readout cycle of the ADC buffer.

iii) To achieve maximum system simplicity compatible with the intended application, data transfer was implemented by software (i.e. flag) control of the 1B wide data path. The transfer speed of this type depends on the system clock frequency and achieves maximally about $2x10^4$ B/s. The data and control signals are connected to an IC: Intel I-82C55, i.e. an universal programmable I/O port and bus addresses: 300 H - 303 H of the standard user reserved area are assigned to this port.

c) Software

Software consists of two programmes – one for on-line, the other for off-line processing. The former presents the stimuli, stores evoked potentials and averages those without artifacts. The parameters of stimulation and recording, i.e. sampling rate and number of samples per trial, respectively, repetition rate and number of stripes are programmable. The number of stripes can be chosen from 1 up to 32. In the case of a single stripe, the stimulation is changed into flicker stimulation when the screen alternates between white and black. The off-line part of the programme package allows for single subject and ensemble averaging and dispersion evaluation as well as for hardcopying of the resulting (averaged) waveforms by a matrix or a laser printer. An example of pattern electroretinogram (PERG) enhanced by averaging of evoked potentials is shown in Fig. 3. The software was developed in Quick Basic with compilation. The on-line programme represents 285 lines of the source code (i.e. 9.2 kB) and 13 KB in the compiled form while the off-line programme represents 306 lines of the source code (10 kB) and 11 kB when compiled.

Results

The described system (Kaminsky *et al.* 1991) was applied to study electrical responses evoked in the rat's retina by patterned visual stimulation (Kittlerová *et al.* 1991) represented by a set of vertical white and black stripes of equal width. The system was based on a simple IBM PC/XT (88) computer with a pair of FDs and an EGA monochrome monitor. The display page switching applied to stimulus presentation used the resolution of 640x350 pixels. The rat's field of vision was limited to a part of the screen while the number of averaged trials and the waveform of averaged potentials were displayed after every ten trials in a separate window of the screen (Fig. 2). The stimulus repetition rate was set to 8 stim/s. The sampling rate of the recorded potential was 250 samples/s and 64 samples per waveform, each waveform corresponding to the visual pattern changes (with the stimulus B-W in the first half and W-B in the second half of the record). All evoked potentials without artifacts were averaged on-line and then were stored on the FD. The artifact detector was activated whenever the recorded potential crossed the limits of a preset amplitude window. Further statistical processing of recorded potentials, including ensemble averaging, was accomplished off-line (Fig. 3).

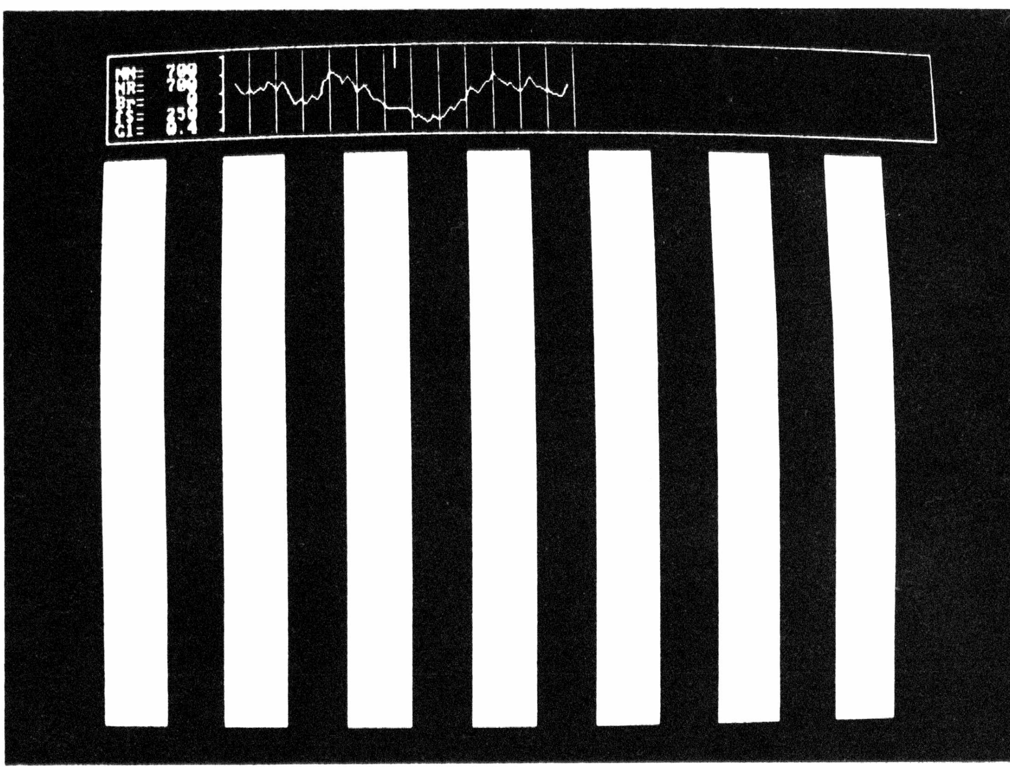

Fig. 2
Picture of the display screen of the on-line programme showing the stimulus pattern and the average of preceding waveforms in the upper horizontal window (where: NN = programmed # of stimuli; NR = # of responses accepted; Br = # of responses rejected by the amplitude filter; fs = interstimulus interval in ms; G1 = ordinate scale in μV). The cursor (short vertical line) marks time instants of the stimulus pattern changes.

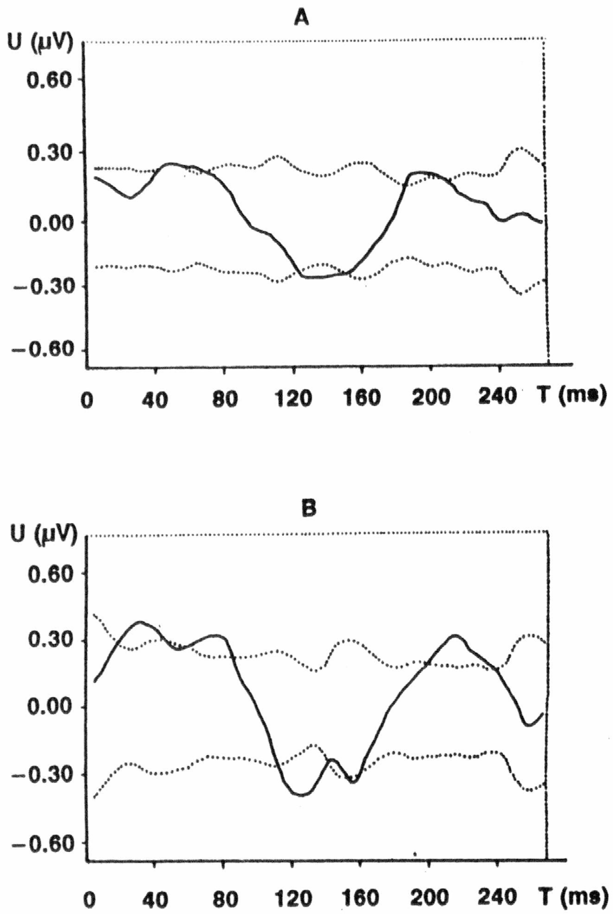

Fig. 3
An example of the retinogram of a rat evoked by visual pattern stimulation: A) average of 9 000 responses, B) ensemble average of 55 000 responses of an intact retina.

Discussion

The described system has been functioning satisfactorily for more than one year, however, it can be improved in the following way.

The stimulation can always be presented at the end of the TV frame, i.e. during the interframe time interval (frame retracing) which will result in a more homogeneous stimuli set. This could be achieved by controlling the page switching time by a flag set by frame synchronization pulse tapped at the output of the EGA display controller.

The number of the simultaneously recorded channels could be increased and the on-line monitoring of the experiment could be enhanced by building the system on an Intel 386 based IBM PC/AT computer.

The system could be readily applied for research and for clinical routine examination in ophthalmology.

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