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COST EFFECTIVE COMPUTERISED ANALYSIS OF BIOLOGICAL SIGNALS

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Abstract: A data acquisition system - using self designed and assembled A/D and D/A converter board and appropriate software - has been developed for the International Business Machine (IBM) Personal Computer and has been used for spectral analysis of bio-electric signals. Spectral analysis of EEG signals was performed and the reliability confirmed by analysis of the same data by a standard systemdeveloped by Dynalog Inc, USA. The cutting edge of the system however, lies in its extreme low cost, combined with the versatility offered due to it being a computer based system.

Key words: fast fourier transform computerised analysis EEG ECG power spectral analysis

INTRODUCTION

Continuously varying biological signals can be represented either in time or in frequency domain. A time domain representation is obtained by measuring the amplitude of the signal at discrete time intervals. A frequency domain representation is obtained by measuring the amplitudes of all the frequencies present in the given signal. Time domain representation can be converted to frequency domain representation by using the Fast Fourier Transformation (FFT). Some frequency compnents have been found to be correlated to certain physiologcal parameters such as the Alpha rhythm of EEG — awake but inattentive person. The sleep stages are characterised by the presence of different types of EEG waveforms in different proportions.

Recently Deepak et al (1) analysed EEG signals using commercially available analysis sytem. The shortcomings noticed were the high cost of the equipment and the low flexibility - restrictions on various input parameters like sampling frequency (max. 256 Hz) and further processing and display of data. In other words the commercially available systems had been preprogrammed to do a specific job and could not be programmed to do anything else. Such shortcomings justified the need of a low cost, high versatility signal analysis system. A data acquisition and processing system - initially designed to record, analyse and reproduce sound signals was found suitable for such purpose. This article describes the theory and application of this data acquisition and processing system, using spectral analysis of EEG signal as a demostrational example.

THEORY

The data acquisition system is an A/D (Analog to Digital) and a D/A (Digital to Analog) device consisting of a hardware circuit along with the appropriate hand-shaking software. The hardware circuit is presently designed for an IBM PC computer. It is directly linked to the micro-processor requiring none of the inbuilt parallel or serial ports. The data and address bus with all the other control lines have been derived from the 62 pin expansion slot on the PC mother board.

Circuit description : The address bus and the micro-processor control lines are decoded using NOR (IC 74LS02) and AND (IC 74LS08) gates. Addtional port selection is done through a 4 bit

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magnitude comparator (IC 74LS85). This decoded data is fed to the demultiplexer (IC 74LS138) which results in the following port usage (selected port & h300) :

&h300 - Start conversion and channel select

&h301 - Data output to D/A converter

&h302 - &h 307 - Output ports

&h300 - &h 307 - Input for A/D converter

&h308 - &h30B - Output/Input ports

The heart of the circuit is the 8-Bit A/D converter - ADC 0809. This chip has 8 selectable analog inputs. Its conversion time is 100 micro-seconds which corresponds to a sampling rate of 10 KHz. A clock frequency of 596.25 KHz is obtained for the A/D converter by dividing the PCs clock frequency (4.77 MHz) using IC 74LS93. End of conversion signal of the A/D converter interrupts the micro-processor (hardware interrupt IQR3) so that data can subsequently be picked up by the micro-processor.

The hardware circuit is also provided with a 8-Bit D/A converter - DAC 800 - for reproducing the stored data. Provision for incorporation of sample and hold devices (IC LF 198/398), analog filtering, amplification and base line adjustment is present.

All software for this system has been written in PASCAL (Turbo Pascal Version 5.0). The hand-shaking section of the software consists of interrupt-handler routines which pick up digital data from the hardware circuit at a specified rate. The signal processing sections consist of routines which perform Power Spectrum analysis, screen displays etc. Power Spectrum analysis routine is based on the routine originally written by N M Brenner of Lincoln Laboratories.

CONSTRUCTION

A general purpose Printed Circuit Board (PCB) (No. E98) has been used for component mounting. IC holders and pin-connectors (for external connections) have been used throughout. The 5V power supply has been derived from the computer itself. A PCB edge connector has been inserted into the 62 pin expansion slot on the PC mother board. This is connected to the hardware board through a flat cable. The components are soldered on to the PCB and the connections made as per the design.

USAGE

As already mentioned, the present data acquisition system is capable of maximum sampling rate of 10 KHz, (corresponding to a 5 KHz Nyquist frequency - which is much more than what is required for most bio-electric signals) which allows the recording of many channels simultaneously. The data resolution is 8-Bit (i.e. the magnitude of each sample of the analog signal is represented as a number between 0 to 255. Thus with an input range of 0-5V, OV corresponds to the number 0, 5V corresponds to the number 255 and any voltage between 0-5V correspond to their respective numbers from 1 to 254). The input voltage accepted by the A/D converter is 0-5V, however, this range can be easily altered.

Because of the above characteristics, this system can be connected to bio-electric amplifiers or to any other electrical transducer and the required analog signal sampled. In this way, records of EEG, ECG, EMG, EOG, etc can be obtained. This data can further be processed, stored, printed and reproduced (through D/A).

EEG signal analysis :

Frequency analysis of biological signals has been an important method of analysis of EEG signals (2). For data acquision the present system was connected to the electrical output connector of the Grass EEG Machine. A spectral analysis of EEG obtained during eyes closed/open, thinking and clenching (with eyes closed) was performed by the computer. A frequency range of 0.5-25 Hz was selected with a sampling rats of 128 Hz and an epoch time of 3 seconds. The sampled EEG record was printed on a standard dot matrix printer. Simultaneous EEG records were obtained from the Grass EEG Machine. The EEG records (Fz-Cz) during eye closing/ opening, their corresponding spectral analysis performed by the present system and the one developed by Dynalog Inc, USA, are shown in Fig 1. In the eye closing Power Spectral Analysis performed by the present system, the maximum peak was obtained at 9.75 Hz and the maximum energy spread was between the frequencies 9-11.25 Hz. The corresponding values for the Dynalog system were 10.5 Hz and 9-11 Hz respectively. Similarly, in the eye opening Power Spectral Analysis performed by the present system, the maximum peaks were obtained at

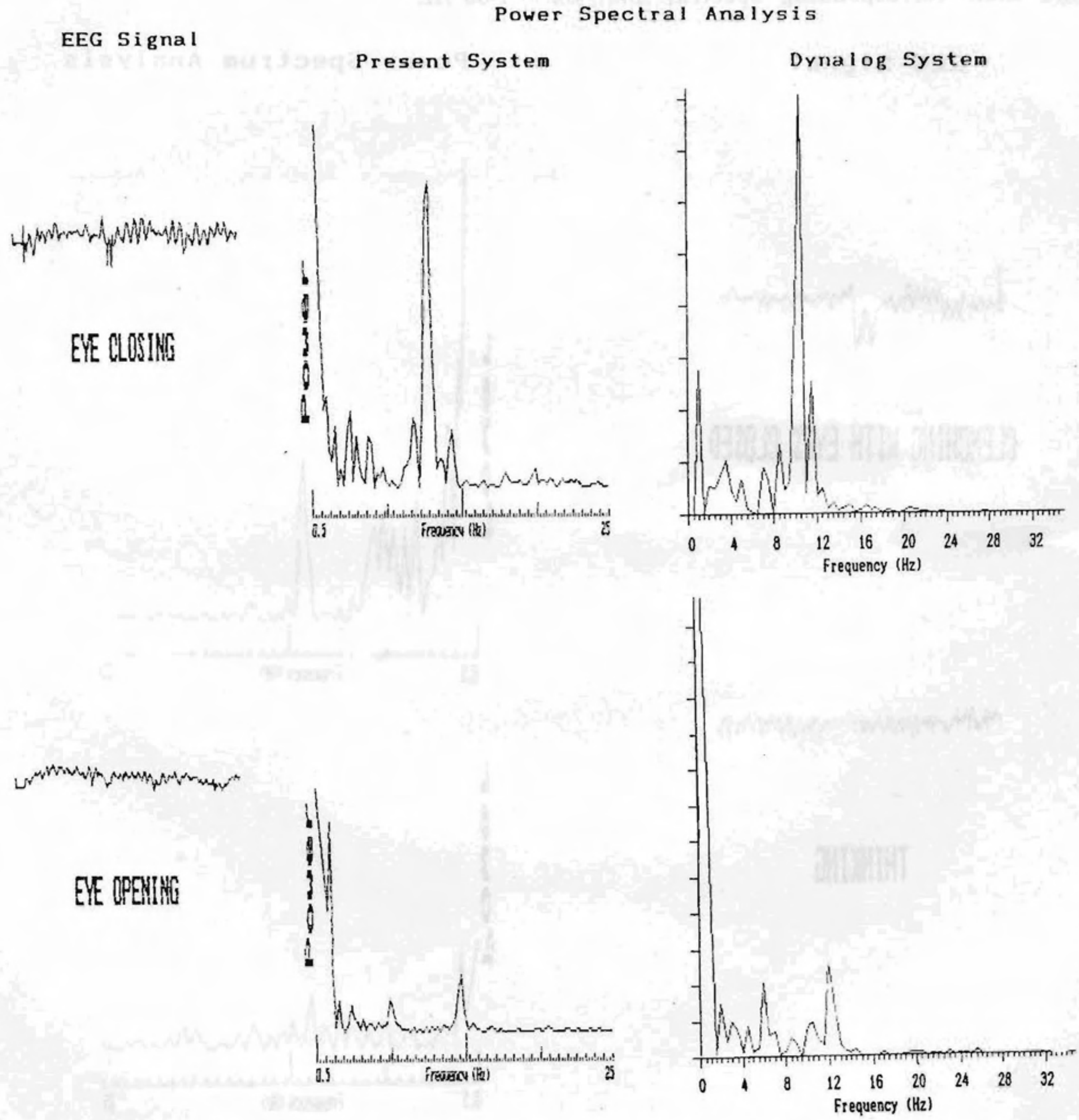

Fig. 1 : Power spectral analysis of EEG (Fz-Cz) signal during eye opening and closing.

6.25 Hz and 12.25 Hz and the corresponding values for the Dynalog system were 6 Hz and 12 Hz respectively. It should be noted that the Dynalog system performed the spectral anaylsis on 16-Bit data while the present system used 8-Bit data. Fig. 2. (A, B) shows the raw signals and their corresponding spectral analysis obtained by the present system. The sampling rate for the ECG Bipolar Lead I and EEG calibration signal was 200 Hz and their approximate respective epoch times were 10 sec and 20 sec. For all EEG signals the frequency response of the Grass EEG Machine was set to 1-35 Hz.

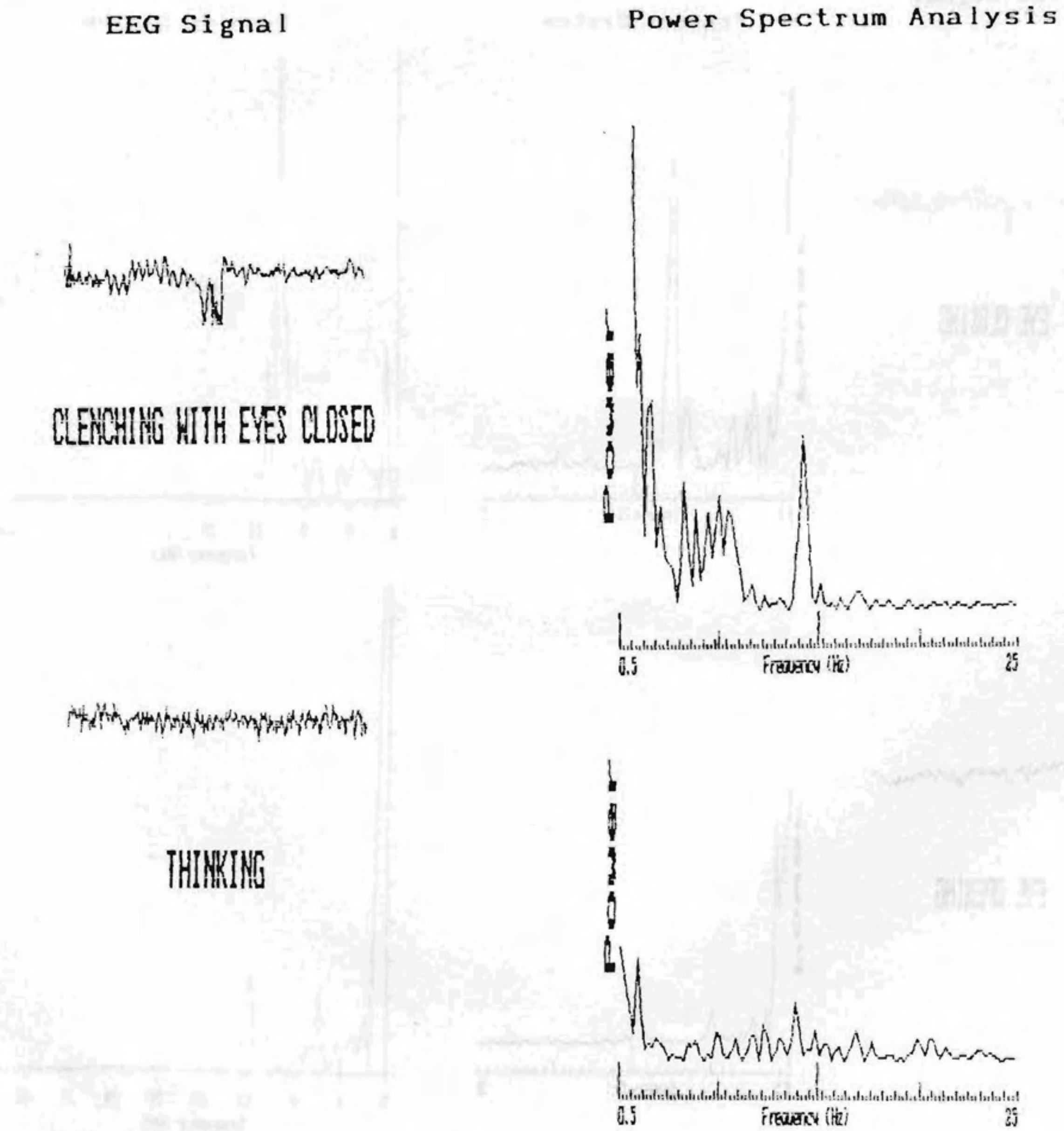

Fig. 2-A : Power spectral analysis of EEG signals as obtained by the present system.

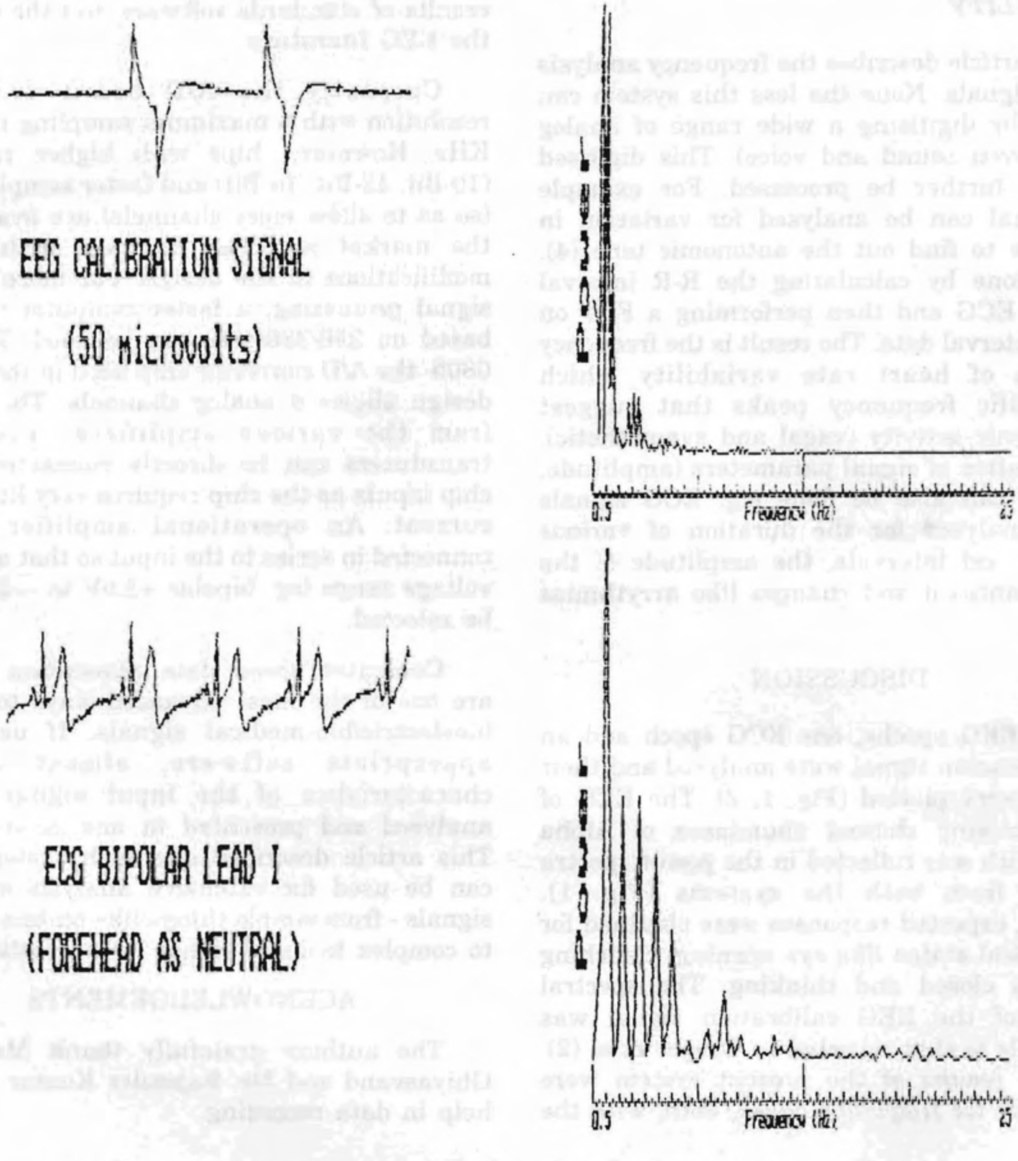

Fig. 2-B : Power spectral analysis of EEG calibration pulse and electrocardiogram signals as obtained by the present system.

RELIABILITY

Computer based systems are very reliable. This is because computer based systems involve digital representation of data rather than the conventional analog representation and therefore do not loose fidelity. Still, a visual matching of the EEG records obtained from the computer and the Grass EEG Machine was carried out, confirming the reliability of this system.

VALIDITY

The validity of this system was confirmed by analysis of the same data by a standard system developed by Dynalog Inc, USA (3).

VERSATILITY

This article describes the frequency analysis of EEG signals. None the less this system can be used for digitising a wide range of analog signals (even sound and voice). This digitised data can further be processed. For example ECG signal can be analysed for variation in heart rate to find out the autonomic tone (4). This is done by calculating the R-R interval from the ECG and then performing a FFT on the R-R interval data. The result is the frequency spectrum of heart rate variability which has specific frequency peaks that suggest specific tonic activity (vagal and sympathetic). Quantification of signal parameters (amplitude, freq, etc) can also be done e.g. ECG signals can be analysed for the duration of various segments and intervals, the amplitude of the waves quantified and changes like arrythmias detected.

DISCUSSION

Four EEG epochs, one ECG epoch and an EEG calibration signal were analysed and their power spectra plotted (Fig. 1, 2). The EEG of the eye closing showed abundance of Alpha waves which was reflected in the power spectra obtained from both the systems (Fig. 1). Similarly, expected responses were obtained for physiological states like eye opening, clenching with eyes closed and thinking. The spectral analysis of the EEG calibration signal was comparable to that reported by Cooper et al (2). Thus the results of the present system were comparable for frequency peaks, both, with the results of standards software and the report in the EEG literature.

Currently the A/D board uses 8-Bit resolution with a maximum sampling rate of 10 KHz. However, chips with higher resolution (10-Bit, 12-Bit, 16-Bit) and faster sampling rates (so as to allow more channels) are available in the market and can be used with certain modifications in the design. For more complex signal processing, a faster computer (IBM PC based on 286/386/486) can be used. The ADC 0809- the A/D converter chip used in the present design allows 8 analog channels. The outputs from the various amplifiers or elctrical transducers can be directly connected to the chip inputs as the chip requires very little input current. An operational amplifier can be connected in series to the input so that a suitable voltage range (eg. bipolar +2.8V to —2.8V) can be selected.

Computer based data acquisition systems are one of the most advanced ways to process bioelectric/bio-medical signals. If used with appropriate software, almost all the characteristics of the input signal can be analysed and presented in any desired form. This article described one such system which can be used for extensive analysis of analog signals - from simple things like on-line displays to complex tasks of signal interpretation.

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