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Instrumentation for Electroretinography: A LED-based Stimulator

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ABSTRACT

In the field of Electroretinography (ERG), new clinical studies begin to show interesting applications of the harmonic analysis of electrophisiological signals obtained in response to flicker-type stimulation of the central retina (macula). The clinical information within this type of signals can be fully exploited only if the experiments are performed using high quality devices, having low distortion and a wide operation range for the stimulation parameters. In this view we developed a stand-alone stimulator that takes advantage from the use of recent optoelectronic devices (the ultra-bright LEDs) and embedded microprocessor control. The instrument, being of simple and reliable operation, was intended as a mean to encourage the introduction of some of the most recent and interesting results of neurophysiological and psychophysical research in the eye clinic.

INTRODUCTION

The generation of a uniform, sinusoidally modulated test light [1] superimposed on an equiluminant background [2] is the key element to realise a flicker-type retinal stimulation. The parameters characterising such a stimulus are temporal frequency, spot size, mean luminance and contrast. Recent studies indicate that by means of a systematic variation of these parameters it is possible to perform a functional analysis of the central retina (macula) and its neuronal elements [3]. The evoked signal emerging from the retinal layers may be simply acquired by eyelid electrodes, provided that low noise amplifiers and effective averaging techniques are used in the acquisition process. The resulting waveform presents harmonic components that indicate the presence of both linear and non linear components in the system under test [4]. First and second harmonic components dominate the response, with a change in their relative ratio according to stimulation frequency. Experimental studies begin to show that the amplitude and phase of these harmonic components are correlated with the activity of cellular elements located in the outer and inner retinal layers respectively [5]. This is the ground were we based the use of the stimulating device presented, that is intended to be used jointly to a PC-based acquisition system [6], to form a practical diagnostic tool.

THE STIMULATOR

To realise reliable experiments based on the described principles it is important to use a modulated light source having good linearity, wide frequency range, fine control of contrast and luminance, low electromagnetic emission. A LED-based stimulator is an attractive choice when such performances are required and when the spatial structure needed is that of a simple, uniform field stimulus. Many authors adopted in fact this solution for their ERG experiments, building devices that differ mainly in the part concerning the LED driver, were a technical effort is needed to solve the problems related to the non-linearity in LED response. The stimulators described in literature [3,7] are usually built using general-purpose laboratory equipment plus some form of dedicated hardware. Our goal was, on the contrary, that of obtain a compact, stand-alone device, to be used not only in a research setting but in clinical routine too. This was made possible mainly by the recent availability of the so-called "ultra-bright LEDs" and by the use of a microprocessor based system control (Fig. 1).

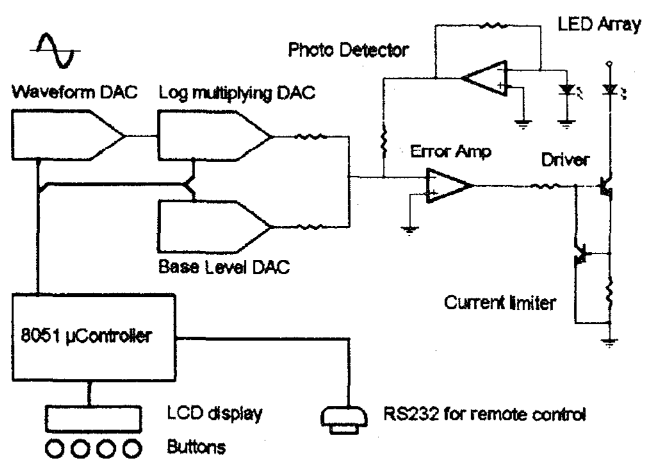

Fig 1. System diagram.

The optical part of the stimulator may be described as a closed reflecting cavity having a circular aperture fitted with a light-diffusing filter. Inside the cavity there is a printed circuit board carrying the LEDs used as light sources and a photo-detector used to monitor the actual light output produced. This light source is fixed at the centre of a Ganzfeld bowl, needed for surrounding light adaptation. To modulate the LED array in a linear way a number of solutions are possible. We decided fôr a feed-back driver, having the advantage to obtain good linearity without sacrificing the resolution. At the same time the effect of thermal modulation at lower frequencies is automatically compensated. The waveform generator that drives the linearized light source is built around an 8051 microcontroller that interfaces with 3 DACs. A virtual lookup table of 64.512 elements is real-time computed starting from a shorter one of 252, resident in ROM. The table is scanned at a fixed sampling rate of 6451 Hz while the desired variation of output frequency is simply obtained by incrementing the scan step from 1 (0.1Hz) to 1000 (100Hz). The use of a separate log-multiplying DAC for amplitude control is an effective way to obtain a fine contrast control directly in decibel, without the burden of real-time calculations or the cost of a digital multiplier. The stimulator thus realised may be characterised by the following ratings: maximum continuous mean luminance of 200 cd/m², total harmonic distortion less than 1%, frequency range of 1 to 100 Hz in 0.1 Hz step, contrast attenuation up to 88.5 dB in 0,375 dB steps, stimulating area of 10 cm in diameter. The user may take control from the front panel console or from the same personal computer used for acquisition, using the standard RS232 link and a simple set of ASCII coded commands.

Results and Conclusion

The stimulator hereby described was used for research and clinical tests in patients affected by various pathologies such as retinitis pigmentosa or cone dystrophy [8]. Fig. 2 is just an example of the type of data this method can yield. First harmonic measurements were obtained from a normal subject tested with a set of 22 stimuli, ranging from 1.5 to 52Hz. The device proved to be reliable, as was possible to appreciate in about two years of clinical use. The good frequency range and resolution is useful to study interaction of cell populations in the inner retina and helps in resolving phase uncertainty at higher frequencies. The 0.1 Hz resolution proved also useful to avoid undesired time correlation between stimulus and sources of periodical noise, such as power line or computer monitors. The minimal distortion of the stimulus allowed a careful evaluation of amplitude and phase of harmonic components in the acquired response. In our opinion the method hereby presented is a simple, effective solution to introduce some of the most recent and interesting results of neurophysiological and psychophysical research in the eye clinic.

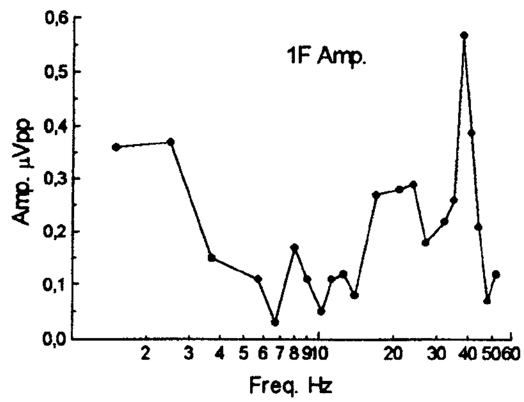

Fig. 2 An example of normative data.

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