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A MICROPROCESSOR-BASED SYSTEM FOR VISUAL EVOKED POTENTIAL MEASUREMENT

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Abstract

A microprocessor-based, visual evoked potential measurement system using a standard color television set has been designed and built. Two modes of operation are provided: (1) a pre-programmed series of basic clinical tests, such as visual acuity or a phase test for multiple sclerosis can be initiated with a START button, using default values which require no specialized knowledge on the part of the clinician, and (2) with the addition of a terminal, the knowledgeable clinician or research worker can choose any desired parameters and sequences within the range of the instrument. Animated color cartoons can be displayed simultaneously to elicit visual fixation in children. The system is automatic even in its sequencing which provides a faster and therefore better and less expensive examination.

1. INTRODUCTION

Visually-elicited brainwaves can be used to help diagnose eye disorders and monitor normal visual development in infants. The brainwave component known as the visual evoked potential (VEP) provides a characteristic trace whose amplitude and phase can be used objectively to measure visual acuity and detect certain disorders, such as multiple sclerosis.

The patient typically is seated in front of a projection screen and watches a changing pattern while wearing ordinary electroencephalographic scalp electrodes. The pattern is altered (e.g., black and white squares are exchanged in a checkerboard or a pattern is briefly exposed without changing the average illumination) and the electrical activity on the scalp is sampled (over a span of time) and stored. The evoked potential signal, about 5μV, is buried in the sea of noise, primarily the electroencephalogram, about 50μV. The stored waveforms are then averaged together so that those parts of the brainwave which are not in response to or synchronized with the visual stimulus increase as the square root of the number of samples of changes. However, the signal increases with the number of samples, providing a VEP plot which rises above the noise level.

2. THE SYSTEM

Unlike earlier schemes using slide projectors with electromechanical shutters, oscillating light sources, or rotating polarized filters, our VEP stimulus patterns are produced on a standard color TV under real-time computer control (see Figure 1). Since the display logic automatically refreshes the screen, the microprocessor (Intersil IM6100) is free to process the evoked potential signals.

Under normal operation the microprocessor writes out information regarding line widths, check edges, quadrant selection (the screen can be divided into four independent quadrants) and contrast levels to the display logic, which in turn maps these parameters onto a 256 × 256 line TV image. In addition, the processor can request sections of the visual field to be deleted (e.g., to blank out the central field and direct the stimulus to the peripheral visual field) and can specify the location of bright spots for use as fixation points.

After setting up the starting pattern, the processor instructs the display logic to provide a stimulus (automatically exchanging black and white), and sampling begins. The number of stimuli remaining are displayed on a 7-segment readout so that time of completion can be estimated. A high-gain, high-impedance, differential amplifier picks up the electrode potentials and presents them to a computer directed analog multiplexer which, in turn, passes the signal into a sample/hold circuit. The output of the sample/hold is held constant while the analog-to-digital converter produces a 12-bit binary word that is proportional to the input signal.

These data words are stored by the microprocessor consecutively in a block of memory called the wave table. Averaging is done by adding each new waveform into the wave table and then dividing through by the number of waves measured.

Finally, the processor plots the averaged waveforms on an X-Y recorder for examination and a permanent record of the examination.

3. COLOR SUPERPOSITION

For children we superimpose color cartoons onto the stimulus pattern, which encourages a spellbound behavior in some patients. Color superposition introduces some interesting problems for the hardware designer. The most serious of these is stable synchronization with the incoming cartoon signal. Since timing errors as small as 50 nanoseconds can can cause severe "tearing" of the image from line-to-line, simple threshold detection is too jittery for use in recovering the horizontal sync signals from the cartoon video. Some VEP investigators have overcome this problem by displaying the VEP stimulus pattern on one TV, the cartoon on a second TV, and optically combining the images. However, to reduce the cost and avoid alignment problems, we remove the jitter by processing this signal through a phase-locked loop which maintains a stable line-to-line timing, irrespective of small variations in the recovered horizontal sync.

After synchronization between the cartoon and VEP display logic has been achieved, the two video signals are algebraically added and sent to the TV. As a consequence, the cartoon's luminance will be heightened by bright pattern lines and lowered by dark ones. Since the chroma subcarrier is not affected, the cartoon's original colors are preserved.

The only drawback with the above method lies in the non-linear nature of picture brightness as a function of video signal amplitude. However, by using stimulus patterns of medium-to-low contrast, only small changes will be added into the cartoon video, resulting in an intensity response that is linear to within a few percent.

4. CLINICAL AND RESEARCH VERSIONS

Since most clinicians desire simple, pushbutton operation, each clinical program may be selected by sense switches on the front panel. By pushing START the microprocessor will put the patient through a pre-programmed battery of standard tests and plot the appropriate VEP results.

However, for the research worker who needs full control over the display patterns and waveform sampling, a teletypewriter or similar terminal can be added to permit specification of parameters without software changes.

5. CONCLUSION

Although older VEP stimulus-averaging systems have been useful in clinical applications, most suffer from low flexibility and high cost, and, above all, a lack of automatic program sequencing. All of these problems are overcome by our microprocessor. This method should not only reduce examination costs in terms of equipment and time, but also markedly improve the quality of examinations.

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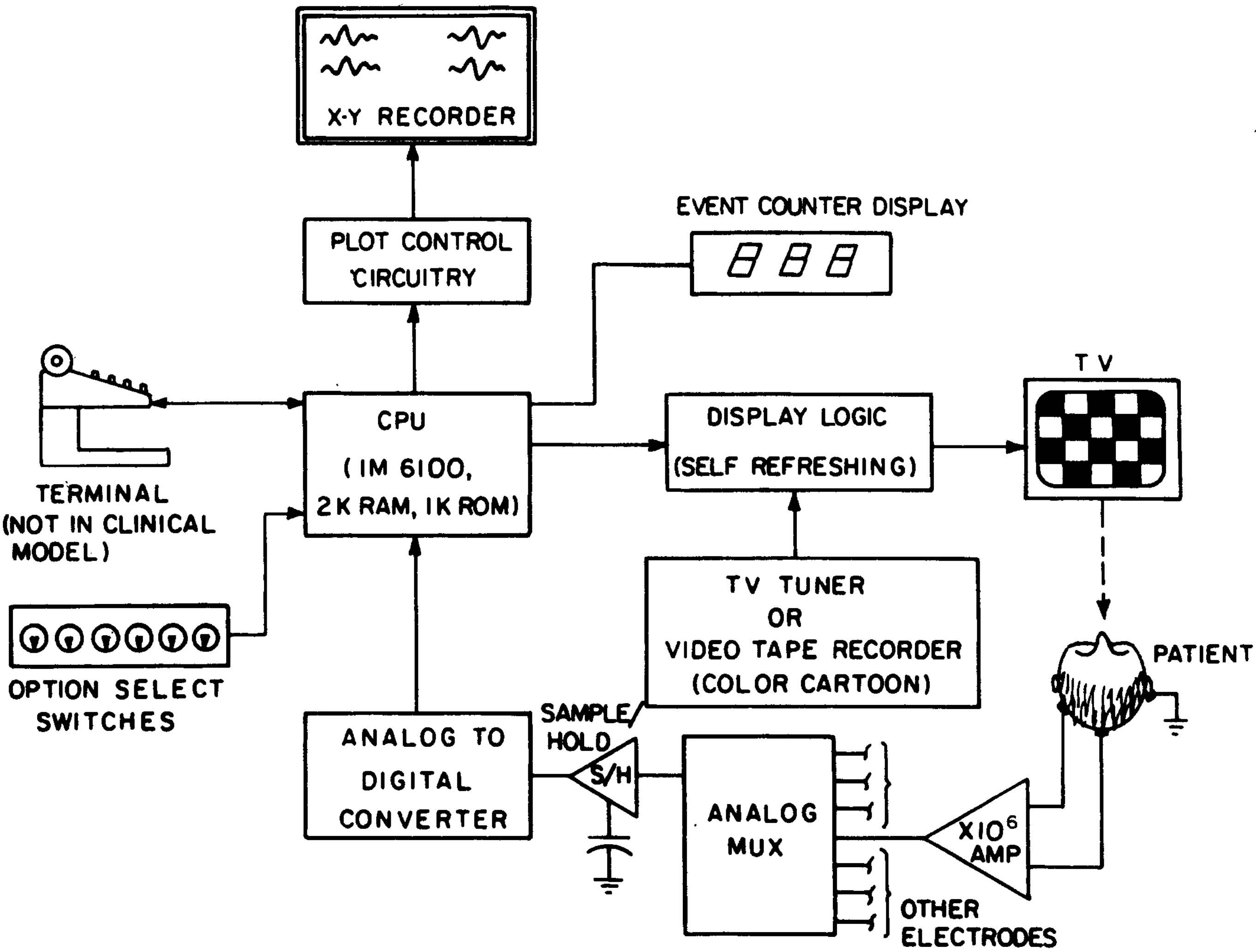
X-Y RECORDER
PLOT CONTROL CIRCUITRY
EVENT COUNTER DISPLAY
TERMINAL (NOT IN CLINICAL MODEL)
CPU
(IM 6100,
2K RAM, 1K ROM)
DISPLAY LOGIC
(SELF REFRESHING)
T V
OPTION SELECT SWITCHES
TV TUNER
OR
VIDEO TAPE RECORDER
(COLOR CARTOON)
PATIENT
SAMPLE/HOLD
ANALOG TO DIGITAL CONVERTER
S/H
ANALOG MUX
X10⁶ AMP
OTHER ELECTRODES