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Electro-Occulogram Based Interactive Robotic Arm Interface for Partially Paralytic Patients

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ABSTRACT

This paper presents a novel idea to control robotic arm movement with the movement of human eyes. Electro-occulography (EOG) is a new technology to sense eye signals through which the robotic arm can be controlled. The signals captured using sensors (electrodes), are first amplified, then noise is removed and then digitized, before being transferred to controller for robotic arm interfacing. The idea is very important in hopes of improving the medium term quality of the life for the physically disabled people who have extremely limited peripheral mobility.

Keywords: *Electro-occulogram, Deterministic Finite Automata, Microcontroller, servo control*

I. INTRODUCTION

Nowadays a lot research is going on in the field of Biomedical Engineering. This field helps and improves our everyday life by applying engineering with the use of computers. *Electro occulography* (EOG) is a new technology of placing electrodes on user's forehead around the eyes to record eye movements. EOG has a very small electrical potential that can be detected using electrodes. These signals are given to the controller through which robotic arm movement can be controlled.

II. IMPLIMENTATION OF EOG

In building this whole circuit, number of components was tried and final component selection was based on optimal performance.

A. SENSING EYE SIGNALS

The generation of the Electro-occulogram (EOG) signal is due to the hyperpolarization and depolarization of retinal cells. The measurement of horizontal eye movements is done by the placement of a pair of electrodes at the outside of the left and right eye. Five silicon-rubber electrodes of impedance below 10 K-ohm are used, placed around the eye to obtain EOG signals. Due to the low impedance range starting from 40-200 Ω [1], the silicon-rubber conducting electrode is more suitable to sense the very low amplitude bio-signals as compared to other types of electrodes such as Ag-AgCl electrodes. Horizontal EOG is measured as a voltage by means of electrodes strategically placed as close as possible to the canthus of each eye. Similarly, vertical EOG is measured as a voltage by means of electrodes placed just above and below the eye as shown in Fig. 1[2]. Due to the higher metabolic rate at the retina compared to the cornea, the eye maintains a voltage of +0.40 to +1.0 millivolts with respect to the retina. This cornea retinal potential, which is roughly aligned with the optic axis and hence rotates with the direction of gaze, can be measured by surface electrodes placed on the skin around the eyes, (see Fig. 1). The actual recorded potentials are smaller in the range of *15 to 200 microvolts* and are usually amplified before processing [2]. With proper calibration, the orientation of the electric dipole can be used to specify the angular position of the eyeball to within 2 degrees vertically and 1.5degrees horizontally .

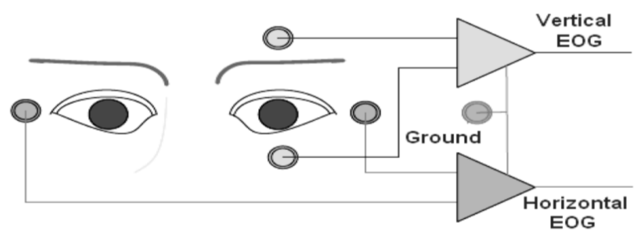

Fig: 1 Correct positions of five electrodes

With the eye at rest no voltage is recorded. The rotation of the eye to the right results in a difference of potential, with the electrode in the direction of movement (i.e., the right) becoming positive relative to the second electrode. (Ideally the difference in potential should be proportional to the sine of the angle.) The opposite effect results from a rotation to the left from right as shown in Fig: 2

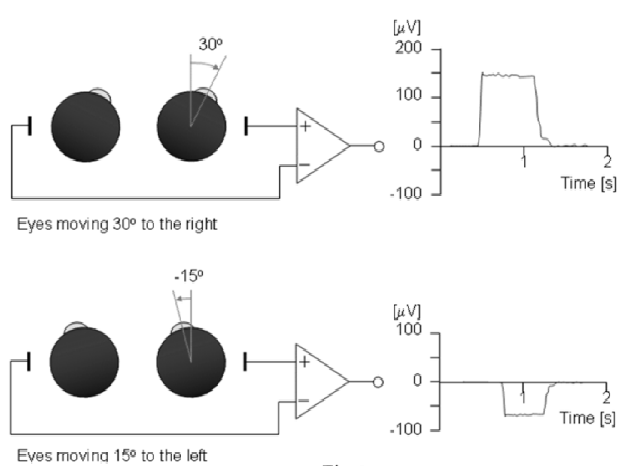

Fig: 2

B. SIGNAL AMPLIFICATION

Number of devices was considered for signal amplification such as A0401 instrumentation amplifier with built-in filters, Eye Sense EOG amplifier, RHA1016, CED1902, but all these devices were very expensive. Some known instrumentation amplifiers were tested such as AD624, INA114, INA118, etc, but all these devices began deviating from their original behavior when applied to such a small range of inputs. There behaviors were verified on Multisim 7.0 Electronics Workbench. *INA126P* is an instrumentation amplifier recognized as EEG/EMG amplifier. It is selected as it can handle signals in microvolt range. Gain of 100,000 is achieved by implementing the amplification phase into two stages, each having a fixed gain of 1,000. This can help in reducing DC offset which may be added due to the skin temperature, the humidity of the air and the skin moisture.

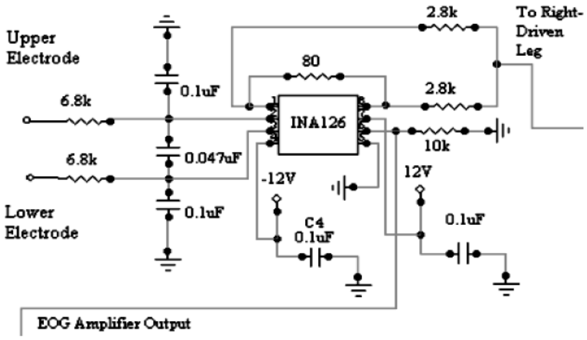

Fig. 3 INA126 with RFI and ESI protection system

As the signal is amplified, the noise may also get amplified. *Radio Frequency (RF) Interference* is a common source having frequency over 10k Hz. Common-mode signals present at the instrumentation amplifier's inputs is normally greatly reduced by the amplifier's common-mode rejection but, at RF frequencies, most instrumentation amplifiers have no common mode rejection . To remove this interference and *Electro-Static Discharge (ESD),* a protection system in the form of an RC low pass filter with cutoff at 47 Hz is implemented at the INA126p's inputs (see Fig. 3). This cutoff frequency can be calculated using (1).

$$f_c = \frac{1}{\left(2\pi\,(R1 + R2)(C3 + C1 + C2)\right)} \qquad (1)$$

C. DRIVEN-RIGHT LEG

IN126P's Common Mode Rejection Ratio (CMRR) is around 94DB. To improve it, a Driven-Right Leg circuit is implemented (see Fig. 4). This circuit is normally used in medical operations because the devices like INA126P read a very small electrical potential from the body and treat it as the desired one. This circuit reads what it believes to be noise and transfers a minute signal back to the body through reference electrode to negate its effect.

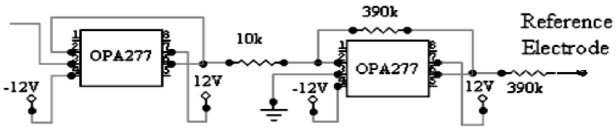

Fig. 4 Driven-right leg

D. OBSERVED WAVEFORMS

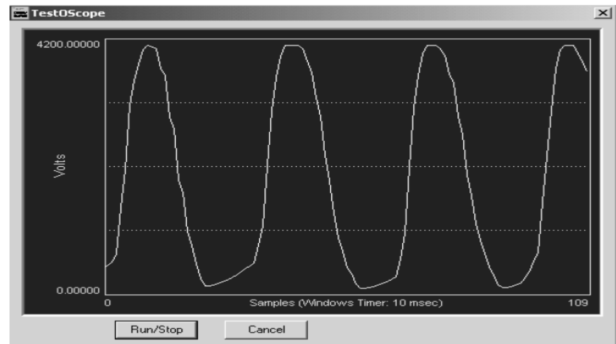

Fig:5 The response when eye blinks

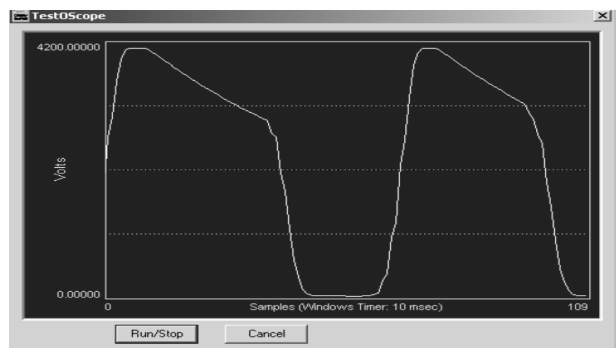

Fig: 6 The response when eyes move up/down

III. ROBOTIC ARM

A **robotic arm** is a robotic manipulator, usually programmable, with similar functions to a human arm .Servo motor is used for joint rotation. It has 5 number of degree of freedom. In order for a robot or a robotic arm to pick up or move something, someone has to tell it to perform several actions in a particular order from moving the arm, to rotating the "wrist" to opening and closing the "hand" or "fingers." So, we can control each joint through controller interfacing [3].

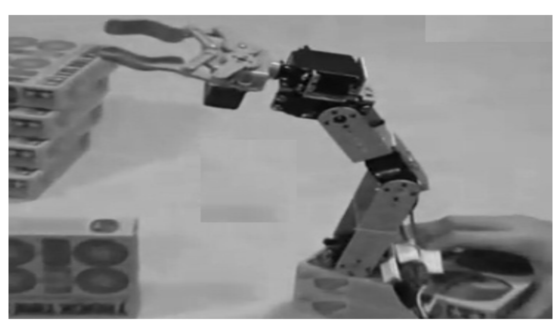

Fig: 7 Robotic Arm Design

A. SERVO CONTROL

A servo motor mainly consists of a DC motor, gear system, a position sensor which is mostly a potentiometer, and control electronics. The DC motor is connected with a gear mechanism which provides feedback to a position sensor which is mostly a potentiometer. The potentiometer changes position corresponding to the current position of the motor. So the change in resistance produces an equivalent change in voltage from the potentiometer. A pulse width modulated signal is fed through the control wire. The pulse width is converted into an equivalent voltage that is compared with that of signal from the potentiometer in an error amplifier. The servo motor can be moved to a desired angular position by sending PWM (pulse width modulated) signals on the control wire.

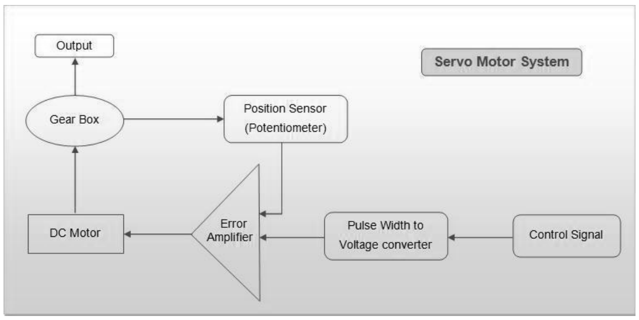

Fig: 8 Servo Control Systems

B. ROBOTIC ARM FEATURES

The arm has five servos which are controlled through the use of only one microcontroller at-mega 16. The arm could grab things approximately in a hemisphere of 50cm and is robust made completely with an aluminium sheet of 2.5mm. The arm could lift objects up to weight of 2 kg. Enabling the base rotation without the help of any gears or ball bearing, also using only low torque servo motors and three castor wheels for rotating the whole body.

IV. EOG INTERFACING WITH ROBOTIC ARM

EOG signals are fed to Micro Controller as primary input to the Peak Detection Deterministic Finite Automata (PDDFA), which based on these signals identifies positive/negative peaks and rest zone in EOG signals obtained from horizontal/vertical channel. The block diagram for this process is shown in Fig. 9.

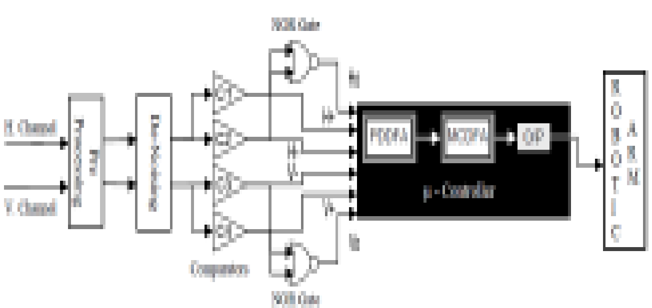

Fig: 9 Block Diagram for EOG Classification Process Flow for a Microcontroller device

The output of PDDFA is used as input by the Movement Classifier Deterministic Finite Automata (MCDFA) to determine which eye-movement was performed by the user [4]. The Movement Classifier Deterministic Finite Automata was developed for Classification of different EOG signals, acquired from horizontal and vertical channels (signal comprises of potential generated due to motion of eye with 2 degrees of freedom horizontal/vertical). We used serial port interface functions for communication between the pc and microcontroller for sending the slider values to atmega 16 for generating the required square wave for driving the servo motors to control the robotic arm. Controller control the robotic arm according to the EOG signals produced by the following movement of eyes as shown in the table (Fig:10).

This Table shows the operations performed by the assisting Robotic Arm for the partially paralyzed patient

• Bio-signals acquired (Data)	Used as command Operation performed by the robot
• Eye ball (left to right/right to left)	Robotic arm movement (180 º)from left to right/right to left
• Eye ball (up/down)	Robotic arm movement from up/down
• Eye-blink (normal 5ms) First eye blink	pick an object (gripper activated)
• Second eye blink	place an object(gripper deactivated)
• Both eyeball and eye blink	Movement of Pick and place in the desired angle

V. CONCLUSION

The approach presented in this work detects the requirements of the subject and aims in assisting to move the object just by moving the eyeball or by blinking the eyes with a response time of 100ms, repeatability 40% and with high sensitivity. Further the design can be enhanced by providing a mechanical moving robot filled with vision and intelligence(Image processing) which can identify different types of objects in a predefined environment which assists the partially paralyzed subject to move the objects according to his will and wish. Improvements can also be done to improve human-machine interaction by exploiting other cognitive states or processes such as anticipation of future events, fatigue in a driver or mental stress.

VI. ACKNOWLEDGEMENT

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