Eye Controlled Typing Using PIC16F877A

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Abstract—People with physical disabilities face a lot of problems in communication with their fellow human beings. In this paper, the design of an eye-controlled system with an emphasis on the *Human-Computer-Interface* (HCI) based on Electroencephalography (EEG) has been presented. The basis for this design is the electric potentials generated by the human eye. After this potential is sensed by electrodes, the signals are amplified, filtered, shifted, and sent into the PIC microcontroller. Also, additional processes were designed to overcome the sources of EEG signals variation. The signals captured using sensors, are first amplified, and then noise is removed and then digitized, before being transferred to PC for software interfacing Using PIC16F877A and RS232 serial communication. Visual basic software is used to build a non-conventional keyboard layout.

Keywords-Human Computer Interaction, Real Time System, PIC Microcontroller, and Electro-encephalography.

I. INTRODUCTION

Today the world has become small village, thanks to computer and technology. The world is getting closer and closer with it. Today, computers are no longer specialized tools used only by scientists or engineers. Computer systems are everywhere- in places you would not expect to find them. They are a fact of life, a common thread that ties together our education, work, and home life

Nowadays, the applications for developing systems to help those people are increased. In these systems, we can see video oculography systems (VOG) or infrared oculography (IROG) based on detecting the eye position using a camera to help these people to control their wheel chair using only their looks or to write on their computers by their eyes, but these methods are still too expensive to be wide spread.

II. THEORITICAL BACKGROUND

A. Eye and Electrodes

Typing on the computer is achieved by eye voluntary movements. This mainly depends on measuring eye's voltage at their different directions by electrodes.

Eye movements:

Human eye is considered as a fixed dipole with positive pole at the cornea and negative pole at the retina [1], as shown in Figure (1), thus front of eye is positively charged. While back is negatively charged, so their movement generates an electric field where the corneoretinal potential can be measured by a pair of electrodes.
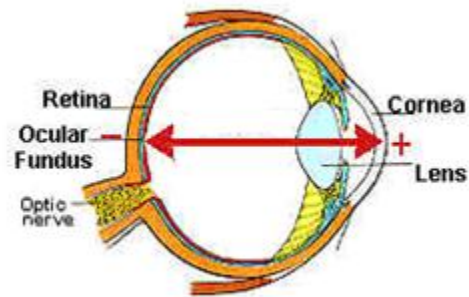

Figure (1): Eye Dipole

Eye moves in different directions as shown in Figure (2), which are straight, up, down, left, right, right up, right down, left up and left down[2].
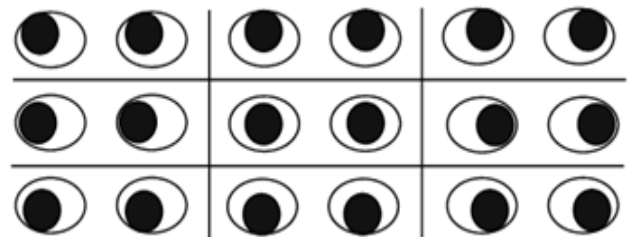

Figure (2): Directions of eye movements

Eye has six muscles control its movements which are the lateral rectus, the medial rectus, the inferior rectus, the superior rectus, the inferior oblique, and the superior oblique [3],as shown in Figure (3). When these muscles exert different tensions, a torque is exerted on the globe that causes it to turn,

in almost pure rotation, with only about one millimeter of translation.
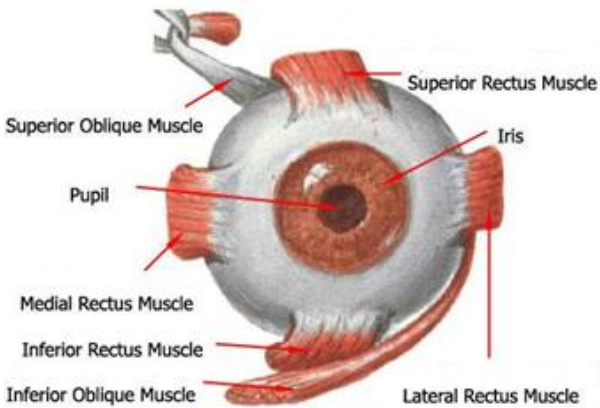

Figure (3): Eye muscles

Electrodes:

An electrode as shown in Figure (4) is an electrical conductor used to make contact with a nonmetallic electrolyte. Electrolyte is any material containing free ions that behaves as an electrically conductive medium between the electrode and human skin [4]. There are different types of electrodes used to measure the electrical activity of various human body parts, such as ECG and EEG electrodes which are used to record the electrical activity of heart and brain, respectively. As well as EMG electrodes are used to record the activation signal of the muscles.

EOG electrodes are used to measure the resting voltage of the retina which makes it the best choice for this project. Unfortunately, they aren't available locally and it was very difficult to get them from abroad, so we were forced to use EEG electrodes to overcome all circumstances and complete this project.

Figure (4): An electrode

B. EEG electrodes Positions

Sensing eye electrical signals by EEG electrodes requires to be attached using the EEG Elefx paste on specific positions on the user face [5] as shown in Figure (5). An electrode is positioned to the right of the eye and another one to the left; these two electrodes sense the horizontal eye movements. Also, two electrodes are positioned to up and down of the eye to sense the vertical eye movements. Note that Silver cup EEG electrodes with impedance 2 ohm are used in this paper.

Figure (5): Positions of EEG electrodes

Since voltage difference is measured between two points, a reference electrode connected to the ground is needed as a common for the four previous electrodes. Ground electrode has different positions. It is positioned on the ear or on the forehead, as shown in Figure (6); the forehead reference electrode is used.

Figure (6): Positions of EEG ground electrodes

EEG Electrodes Test

It is necessary to test EEG electrodes before use. Electrodes test checks its conductivity, its output resistance and its ability of sensing eye movements which are straight, up, down, right and left. Test results are shown in Figure (7a, 7b, 7c, 7d).
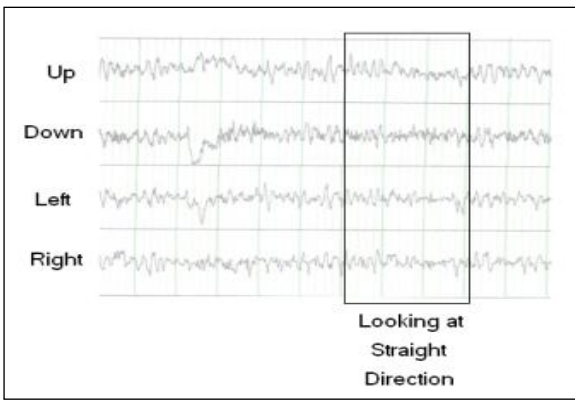
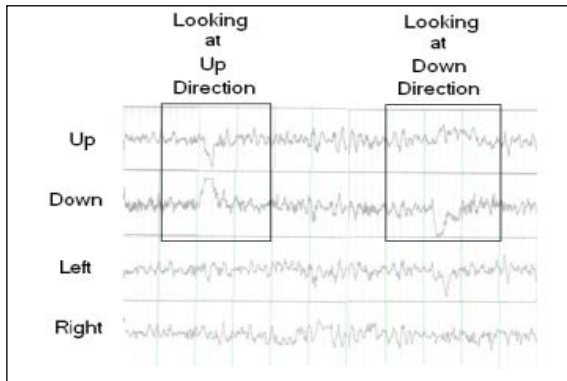Figure (7a) Response of looking straight forward

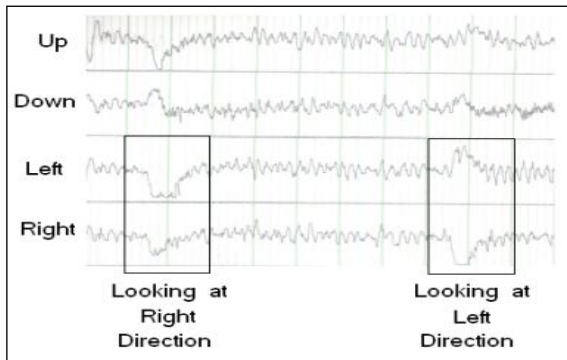Figure (7b) Response of looking up and down

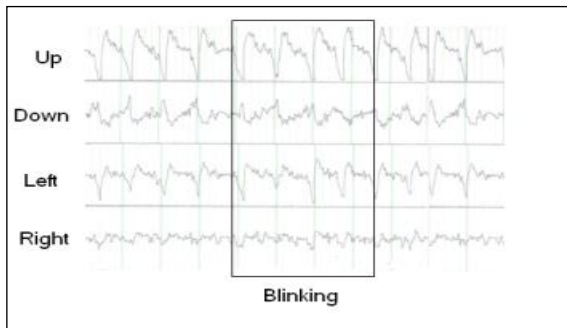Figure (7c) Response of looking right and left

Figure (7d) Blinking response: Results of EEG electrodes test

When eye moves in a certain direction, its electrical signal which the electrode has sensed is different. This paper aims to distinguish these movements and process each one individually. During this EEG electrodes test, looking straight forward gives equapotential up, down, right and left electrical signals as shown in Figure (7a). While in Figure (7.b), eye moves in the vertical direction so it doesn't affect right and left electrical signals. The horizontal movements do not affect vertical electrical signals as shown in Figures (7c). This test was performed by using the ' EEG Teca 1121 Vikens Medical Device ' shown in Figure (8).

Figure (8): EEG Teca 1121 Vikens Medical Device

III.   Design

In building this whole circuit, number of components was tried and final component selection was based on optimal performance. Block diagram of the system is shown in Figure (9), which includes both the hardware and software components.
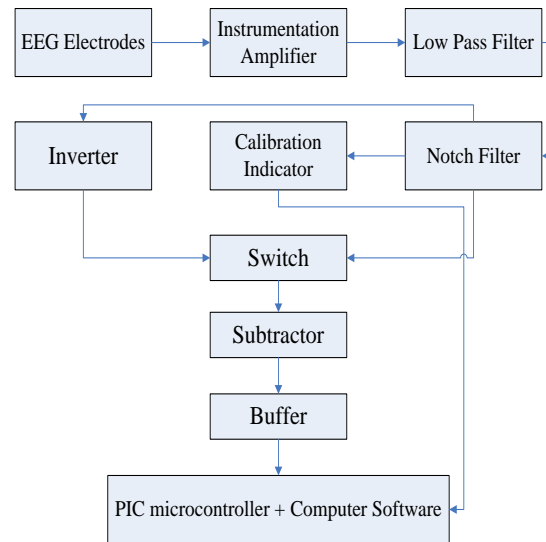

Figure (9): Block Diagram of Eye Controlled Typing project.

A. Hardware Components:

INA118 Instrumentation Amplifier

The EEG signal is a result of a number of factors, including eyeball and eyelid movement, different sources of artifact such as EEG, electrodes placement, head movement and influence of the luminance, etc. For this reason, it is necessary to eliminate the shifting resting potential (mean value) because this value changes [6]. To avoid this problem, it is necessary to have ac differential amplifier that will take the difference of the two opposite electrodes. Eye electrical signals have been sensed and needed to be amplified via INA118 is used. The controllable gain computed using Equation (1).

$$G = 1 + \frac{50k\Omega}{RG} \tag{1}$$

Constant gain can be used through adjusting RG resistor but practical tests result in different EEG amplitude voltages for different persons. This difference in EEG voltages for different persons may be so large. Thus using constant gain would cause many problems later. These problems are caused because amplified voltages will be processed with microcontrollers which accepts limited input in a restricted range so variable gain is needed to suit any user state and the amplified signals still in the demanded range, So RG is set to a variable resistor which will be tuned until a certain LED flashes indicating suitable gain.

Practically, the difference between right and left signals or up and down signals was in the range of 2 to 100 mV. Adjusting the straight voltage at 2.6 volt requires gain at the range of (2.6/100mV) to (2.6V/2mV) which is 27.316 to 1300. Obtaining this range of gain requires the adjusting resistor to be at the range of (38.5 to 1.9k) ohm by applying Equation 1. Thus a 2kΩ variable resistor was suitable to be used as RG.

Low Pass Filter

INA118 amplifier has cut off frequency of 7 kHz, and the highest eye signal frequency is 32Hz. Thus our interested range of frequencies is not affected by the instrumentation amplifier band and this is another reason to use INA118A amplifier. Any noise component with a frequency higher than 32Hz is cut using low pass filter with fc = 32 Hz. Using equation 2 , R=5kΩ and C=1μF to meet the cut of frequency as shown in Figure (10).
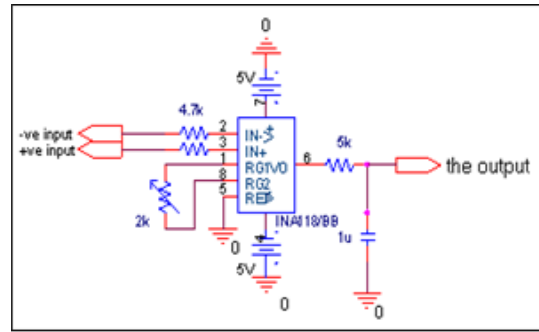
$$f_c = \frac{1}{2\pi RC} \tag{2}$$

Figure (10): Instrumentation Amplifier and LPF design

Practically, the range of the frequencies of the signal at the LPF output was 32Hz and the signal vanished at the higher frequencies.

Notch Filter

The most critical problem that needs one's attention is the power line noise. It ranges from *50 to 60Hz*. The main source of this is the fact that the subject's head behaves as an antenna allowing a capacitance to be set up between overhead fluorescent lighting and the patient's head, with the air behaving as a dielectric. Similarly nearby electrical equipment induces power line noise, introducing interference [7]. A simple Notch filter with 50 Hz cutoff is implemented to counter this problem Notch filter blocks out a 50 Hz power line to avoid its effect on EEG electrodes sensitivity. It's realized by HPF cascaded with LPF using operational amplifiers as shown in Figure (11). The filter passes all frequencies except for the range of a 49–51 Hz. This would be used to filter out main harmonics from a 50 Hz power line; however its higher harmonics could still be present.
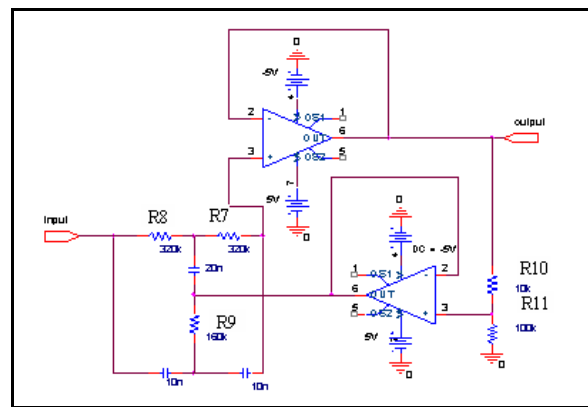

Figure (11): Notch filter design

Practically: the signal was filtered from the 50Hz frequency and it was more suitable to be viewed on the digital oscilloscope at the laboratory.

Practical work shows that the amplified filtered voltage could be positive or negative and   since negative voltage is a state which PIC16F877A doesn't accept and turns it to zero, a calibration indicator to inform the user with his voltage polarity is used. Calibration indicator is combined of a comparator and a LED, this comparator is built using Op-Amps with grounded reference as shown in Figure (12).
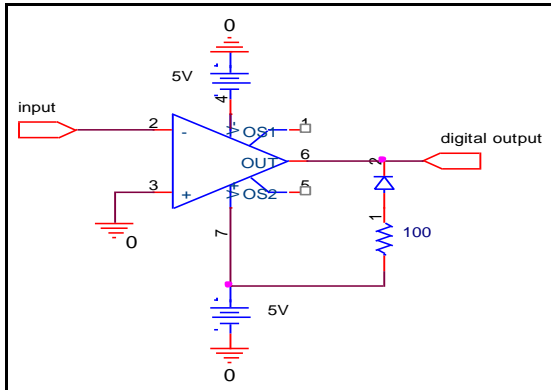

Figure (12): Calibration indicator circuit.

Comparator output will be treated as a digital input to PIC16F877A which will find during its programming the state of the voltage and indicates it with a LED. If the voltage is positive the led will turn on and vice versa.

Inverter

When the led turns off indicating a negative voltage, it is necessary to invert it to get a positive voltage to suit PIC processing. Simply, the inverter is built using Op-Amp amplifier with gain of -1, in which the input 'R$_i$' and feedback 'R$_f$' resistances are equal as shown in Figure (13) resulting in an equal output and input voltages with inverted sign.
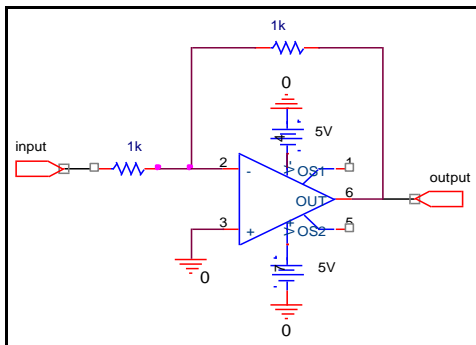

Figure (13): Inverter circuit

Switching Stage

PIC16F877A doesn't accept negative voltages which necessitate using positive voltage as the PIC input [8]; on-off switch is used to select the positive voltage either before the inverter or after it. This selection will be done manually by the user according to the calibration indicator (LED). The switch has three terminals as shown in Figure (14). It is a mechanical device used to connect and disconnect the components of electric circuit.

Figure (14): Three terminal on-off switch

The selected voltage will be applied to a subtractor, buffer circuit then to PIC16F877A.

Subtractor

Low sensitivity of EEG electrodes necessitates more amplification with avoiding the saturation case. So, a subtractor as shown in Figure (15) is used to solve this problem. The straight voltage is adjusted at 2.6 volt, a voltage of 2.5 volt is subtracted and the result which is 0.1 volt is amplified.

INA118 instrumentation amplifier is used for amplification. Its gain is adjusted at 31 that it has R$_G$ with a value of 1.65kΩ, that the straight value will be 3.1 volt and higher for up and right directions and lower for down and left directions. After the subtractor more significant voltages for the different eye movements are distinguished.
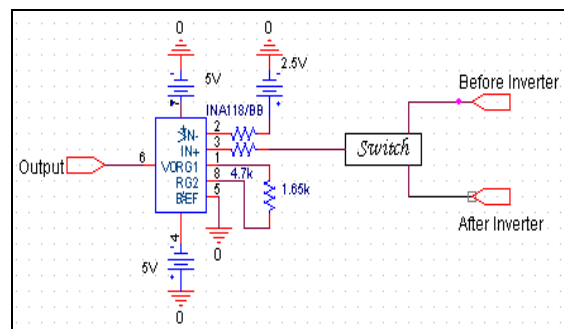

Figure (15) subtractor circuit

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Buffer circuit

A unity gain buffer circuit shown in Figure (16) is used to lower the output impedance of the overall circuit. This ensures the majority of the signal will be transferred to PIC16F877A. Because PIC16F877A doesn't accept negative voltage, a diode is used at the subtractor output to get zero voltage if the result of the subtraction is negative to ensure that no negative voltage will reach the PIC at any case. Diode causes the voltage to be lowered by 0.2 volt thus the straight voltage will reach the PIC with the value of 2.9 volt.
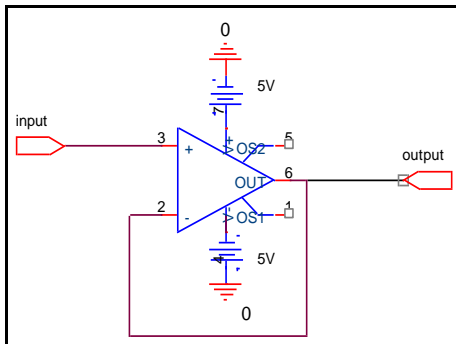

Figure (16): Buffer circuit.

Power Supply Module

A power supply of +5V and -5V is used in, and it will provide power to all the amplifiers, PIC, and MAX232. This module will add portability to our product. UA7805C and UA7905C regulators are used to get +5 and -5 volts, respectively as shown in Figure (17). Practically, the values of the sources were 4.8 and -5.1 volt.
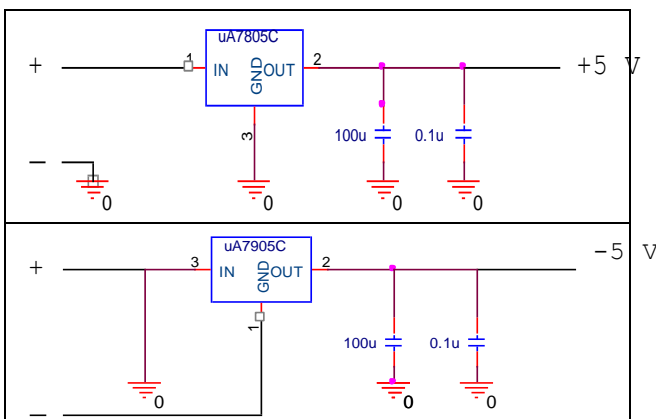

Figure (17): +5V & -5V power supply schematic

Design Test

Each stage discussed in this section is tested using Orcad software tool. The whole system design is tested by fitting INA118 amplifier, passive LPF, notch filter; calibration indicator and the inverter together then apply EEG signals to the hardware components. The results of the test using digital oscilloscope are displayed in Figures (18) and Figure (19):

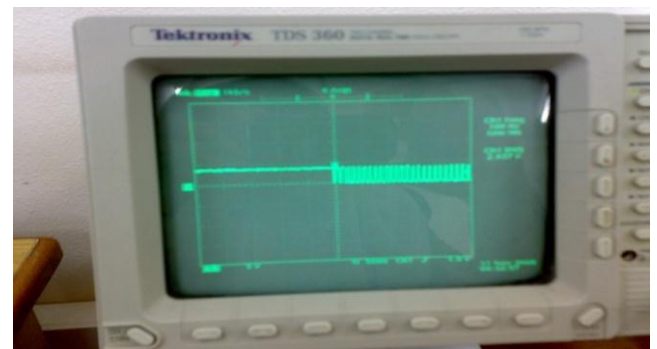Figure (18): Response of looking down then up

Figure (19): Response of looking right then left

Figures (18) and Figure (19) show the obvious difference between electrical signals of right and left, down and up and how does it change according to the movements of eye. It is clear that looking right gives higher voltage than looking left and looking up gives higher voltage than looking down. These signals are ready to be processed with PIC16F877A.

B. Software Components:

PIC16F877A programming

PIC16F877A performed 10-bit ADC with +5v as Vref+ and 0V as Vref- on the horizontal and vertical input voltages, besides controlling the directions of the keyboard layout based on some data analysis on the two 10-bit data [9] . Figure (20) shows that according to the horizontal and vertical inputs, the

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output will be specified either 1 for looking up, or 2 for looking left, or 4 for looking right and 5 for looking down, extra undesired directions are programmed to be sent to the computer as zeros.
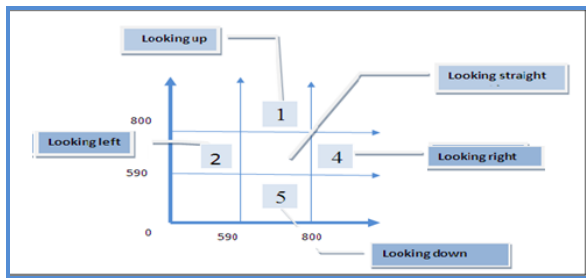

Figure (20): Programming Idea

The values of horizontal and vertical inputs which are on the axes are logic since PIC16F877A converts the analog into digital with 10 bit sensitivity, both the axes will started from 0 to 1023 which is the range of 1024 (2^{10} the maximum value of the quantization level in the digitalization process).

PIC16F877A Hardware Test

PIC16F877A tested using hardware circuit which displays the output using four LEDs beside two LEDs for horizontal and vertical calibration.

It is tested also using Proteus; Proteus is a commercial software product which allows simulation of many PIC devices along with a wide array of peripheral devices, so it can be used as a hardware test using software tools as Figure (21) shows; the output of 2 which appears when the user looks left.

MAX232 chip and RS232 serial port are connected to complete PIC16F877A design as shown in Figure (27)
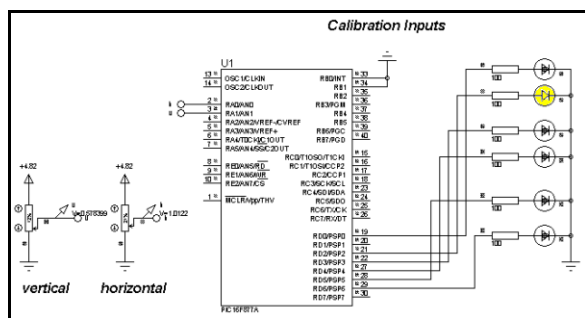

Figure (21): Proteus schematic diagram

Software Visual design

Microsoft Visual Basic 6.0 is used in this paper because of its easy programming, easy displaying of visual elements, availability. That's it is one of the most popular programming languages and it is easy to implement functions using it [10].

Keyboard layout is the user interface which is used in this paper. A non-conventional keyboard layout is built using visual basic language because a regular keyboard layout is not easy to be controlled by eye movements and the fact that EEG electrodes can distinguish only the main directions. The software user interface will looks like a non-conventional keyboard layout. One key on the keyboard will be activated at a time, indicating the key that the user is currently looking at. The software takes in the data coming in through the serial port, and determines which key to shift to, or whether a key press is made. A text display window will present the typed letters, which located at the top of each form

Visual software Keyboard Design

Designing the visual keyboard is based on directions which the previous design can distinguish it obviously. Different numbers received by serial represents different directions. Receiving a certain number means that the user looks at the task in the direction represented by this number so this task will be done. Thus the tasks are distributed on each form at the right, left, up and down directions. Working on these four directions only requires many forms to represent all letters and numbers, and typing process may be inefficient but using better electrodes will solve all these problems, that's distinguishing more directions will increase the number of tasks in the same form and thus decreases the total number of forms. Consequently, the size of the software design will decrease. More tasks can be also available for the user such as coloring the text or listening to music.

Working on the horizontal direction, 0 and 1 can be typed on the text when the user looks at them. The result of typing is shown in Figure (22). Saving typed text as a text file or a word document file shown in Figure (23) and Figure (24).
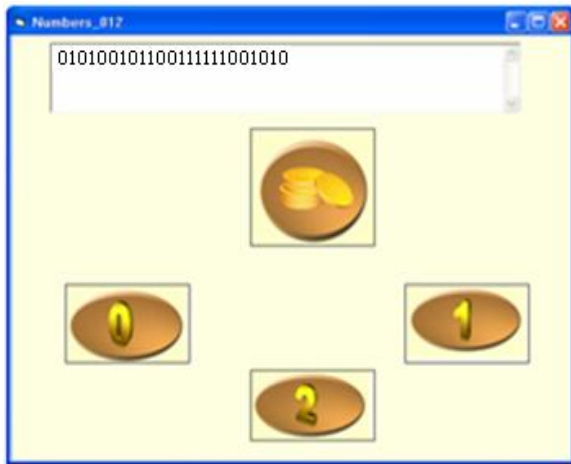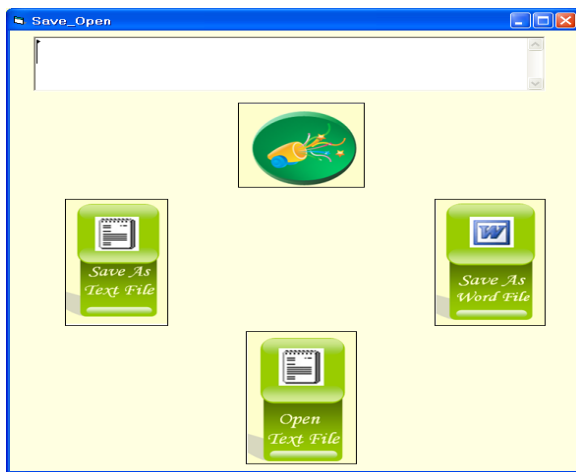
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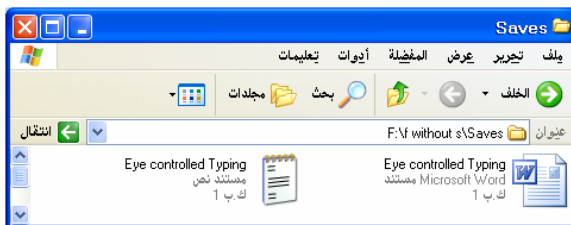Figure (22): Typing Result

Figure (23): Save- Open Interface

Figure (24): Saving the typed text Result

IV.   CONCLUTION

A human computer interface with basic functionality is successfully implemented and demonstrated. This paper has proved practically that it is possible to control a computer by eye movements using electrodes placed around the eyes. Individually, the system design stages mentioned were tested to function properly. Hardware circuit of each stage of the system design gave the expected output values when tested alone. The function generator was used as input to the PIC; the expected alphabets were typed into the software interface.

The major problem was that the signals coming from the electrodes are not stable enough. The slightest movement will cause the voltage levels to fluctuate. As the electrodes starts to become loose, the signal also starts to shift up or down. However, the amplifier gain that may be required to achieve a meaningful signal may change from a person to another, and the circuitry could be modified to allow a variable amplifier gain. A variable resistor in the design of the large inverting amplifier has been suggested to facilitate this as problem solution.

Also low sensitivity of EEG electrodes was the real challenge in this paper that's the difference between looking right and left is very small, to overcome this problem sub tractor and amplifier are used to increase this difference and make PIC16F877A able to distinguish eye movements.

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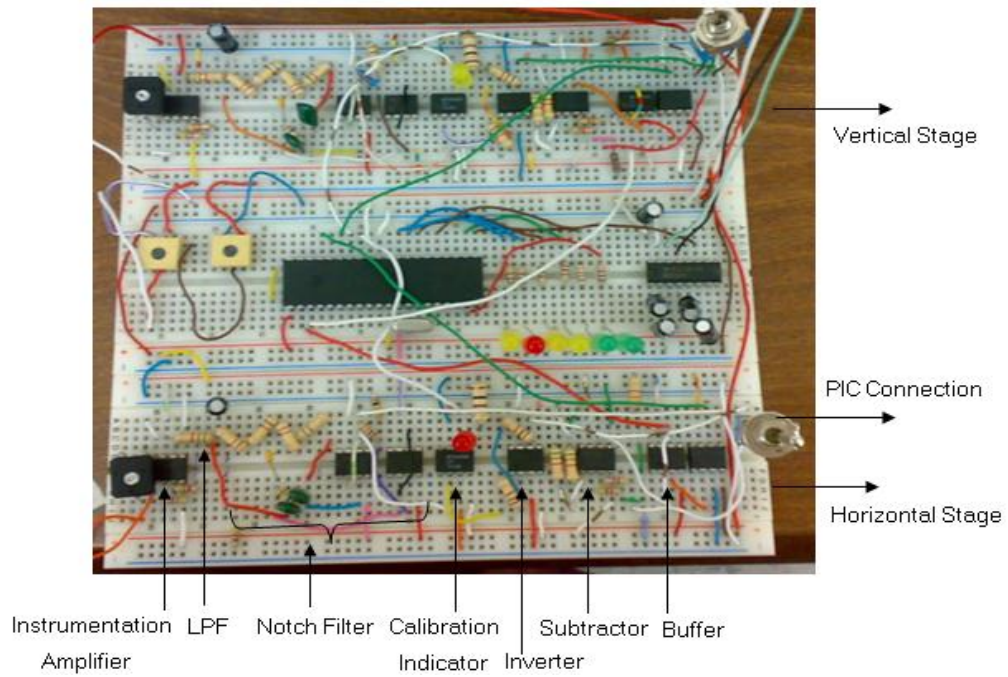
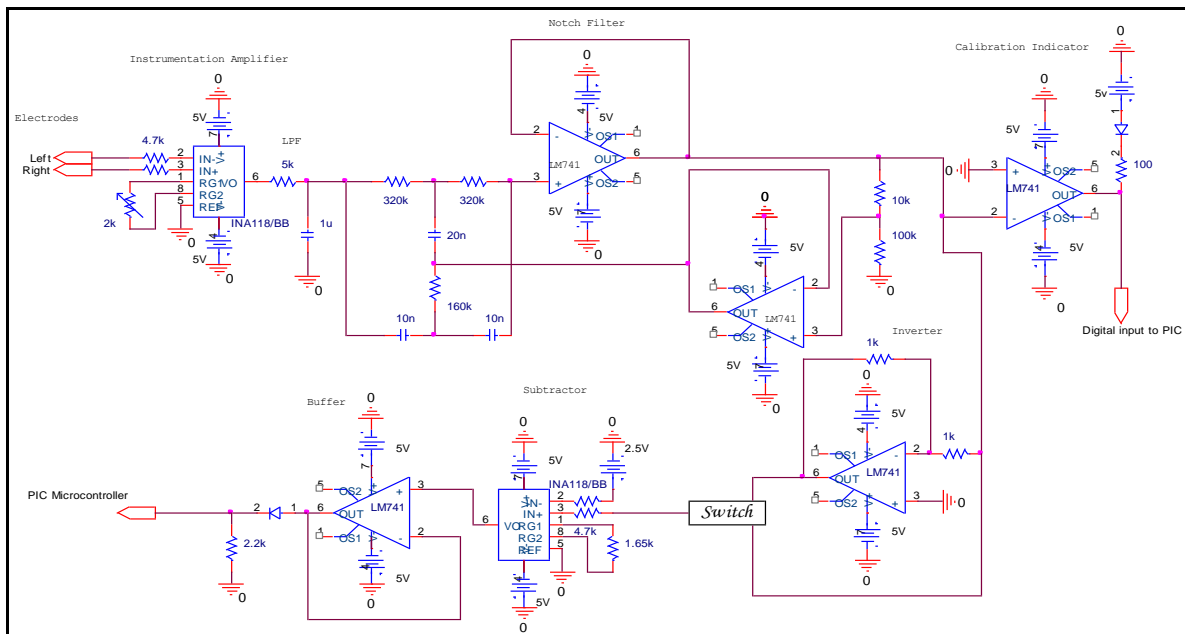Figure (25): Full hardware design Connection

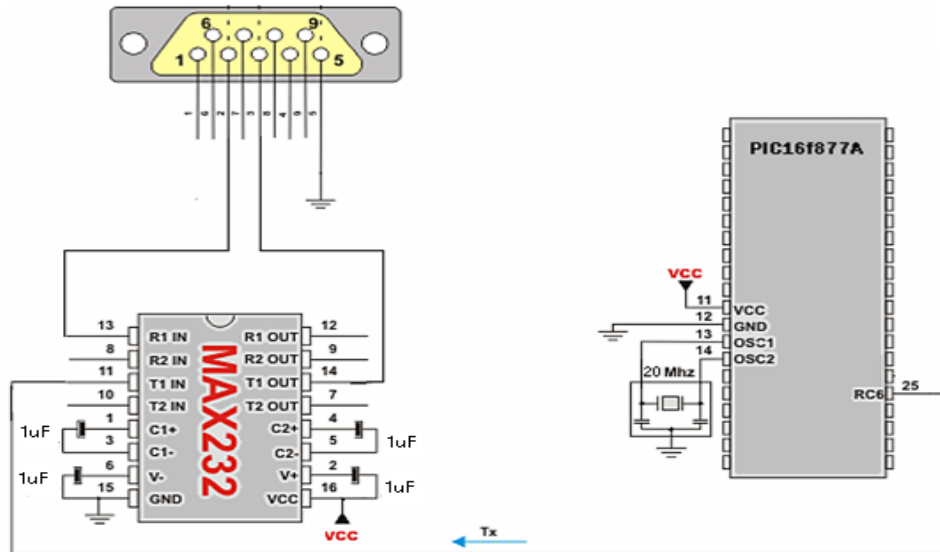Figure (26): Schematic of Hardware circuit
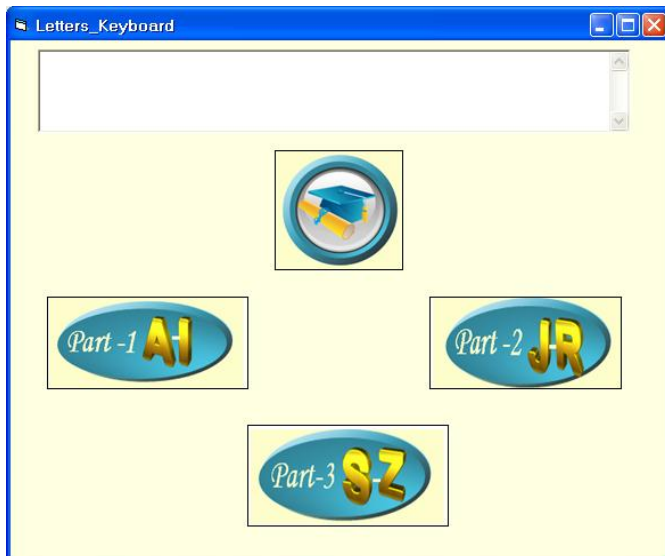
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Figure (27) Schematic of the PIC Microcontroller Interface with Max232

Figure (28): Letters Keyboard Interface