Computer Access Devices for Severly Motor-disability Using Bio-potentials

SUNG-JAE JUNG[1], NAM-EUK HER[1], IL-HWAN KIM[1]
[1]Department of Electrical and Electronic Engineering, College of Information Technology
Kanwon National Univ. Chuncheon Korea..

Abstract: - In this paper, we describe implementation of a computer access device for severly motor-disability. Those who are totally paralyzed, or "locked-in" cannot use conventional augmentative technologies, all of which require some measure of muscle control. The forehead is often the last site to suffer degradation in cases of severe disability and degenerative disease. We uses brain and body forehead bio-potentials in a novel way to generate multiple signals for computer control inputs. A bio-amplifier within this device separates the forehead signal into three frequency channels. The lowest channel is responsive to bio-potentials resulting from eye motion, and second channel is band pass derived between 0.5 and 45Hz, falling within the accepted Electroencephalographic(EEG) range. A digital processing station subdivides this region into eleven components frequency bands using FFT algorithm. The third channel is defined as an Electromyographic(EMG) signal. It responds to contractions of facial muscles and is well suited to discrete on/off switch closures, keyboard commands. We confirmed the performance and availability of the developed system with experimental user's bio-potentials.

Key-Words: - bio-potentials, EEG, EMG, EOG, FFT

1 Introduction

Many people with severe motor disabilities need augmentative communication technology. Those who are totally paralyzed, "locked-in", or ALS(Amyotrophic Lateral Sclerosis) known as Lou Gehrig's disease cannot use conventional augmentative technologies, all of which require some measure of muscle control . Over the past decades, a variety of studies has evaluated the possibility that brain signals recorded from the scalp or from within the brain could provide new augmentative technology that does not require muscle control[4]. In the case of locked-in syndrome, patients cannot move their bodies at all but can blink their eyes. In addition, some disabled people can move their facial muscles to a certain degree. Thus, the signal applicable to the control input signal in the bio signals generated from the face is not regular but becomes different from patients. In a word, the performance of systems will be generally improved in case the signal of which applicability is highest is used to the control input signal. On this score, in this study a portable hardware was designed in order that bio potential can be used to control input signals in computers as well as the effectivity and of the bio signal taken in this way and its applicability were verified by application software. In this study, very minute bio potential of several microvolts taken from the electrodes adhered to the forehead was amplified through an amplifier and a filter. Afterwards, the filtered signal was classified as to bio signal.

The signal classified in this way can be suitable to the conditions of subjects as it is individually used. It has been difficult for patients to use the existing electroencephalographies due to high price and complicated manuals. With intent to solve such problems, this system was simple as far as possible and portability and its applicability were improved. Low power consumption is necessary to improve portability, and so this system is operated by a battery but cuts off electrical consumption at ordinary times.

The bio-potential signal taken from the electrode is amplified and its external noises are removed in process of passing through a preamplifier and a band-pass filter, and the amplified signal is inputted into a microcontroller through an A/D converter. The microcontroller digitizes the input signal and transmits the result to the PC through serial communications. In case of processing the digital signal, time-series data is converted into the data in a frequency band by using FFT(Fast Fourier Transform) algorithm[10].

Users can check signal amplitude in a frequency band on a monitor in real-time. Users should try to find out the correlation between their bio signals shown in

real-time and his intention, and should try to control such signals. Users will be able to control their bio signals as much as they want by appropriate practices and feedbacks.

2 The Designed System

2.1 Bio signals

The bio-potentials measured on the human scalp include various signals. In particular, EEG (Electroencephalogram), EMG(Electromyogram) and EOG(Electrooculogram) are ones of major bio signals. EOG signals are ordinarily generated by moving eyes, and EEG signals are generated by moving facial muscles. EMG and EOG are called 'Artifact'. As these artifact signals hinder in pure EEG analysis, various studies have been carried out to remove such artifact signals[6][7]. However, the three signals, i.e., EEG, EMG and EOG, were all applied to this system so that such signals can be used as to patient's state. EEG pattern has a shape of sign wave. Ordinarily, the range between peaks is between 0.5 and 100uV. This value is equivalent to one hundredth of the ECG(electrocardiogram) signal [7]. The initial power spectrum of EEG signal can be calculated by Fourier Transform. Also the spectrum of the sign wave, which has different frequencies, can be calculated. Granted the spectrum is successive, individual brains can dominantly generate a specific frequency between 0Hz and a half of the sample frequency.

2.2 System Configuration

Fig.1 shows the configuration of general system. It is basically constituted by a signal-inputting unit, power unit, a signal processing unit and a communication part. The signal-inputting unit removes and filters noises in the signal inputted from the electrode on the forehead, and sorts out suitable frequency band and transmits the signal to the signal-processing unit. A PC makes loud noises because various electronic elements such as a power supplier and fan are basically equipped in it. In case those noises are interfaced without filtering, the system will be remarkably affected. Particularly, a circuit that amplifies minute signals including bio potential is more affected. The photocoupler-based insulating circuit was made out to remove noises made by PCs. The battery is used in this system so that it can be portable. Also, it is constituted by a DC-DC converter that converts the voltages of

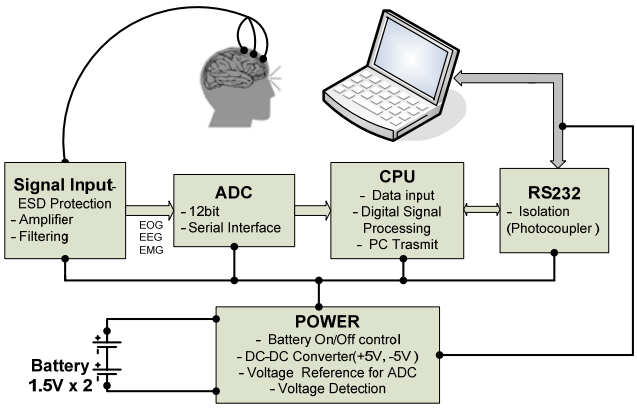

Fig.1 System configuration

batteries into the working voltage of other elements including OP-Amp and a powering unit that generates the reference voltage of an A/D convert. And, electrical consumption should be cut off when it is off work in order that it can be used as long as possible; actually, electric power is controlled by a circuit that senses connecting with a PC.

2.2.1 Bio-Potential Signal

The brainwave generated from the forehead and the bio potential generated from the human body are used in this system, in order to generate the multiple signals applicable to the control input signal. On the forehead, 3 bio electrodes made of silver chloride(AgCl) are adhered by using a headband. Each electrode can detect even the bio potential of 0.3uV. As such electrodes are noninvasive types, it can detect signals repeatedly. Impedance level is less than $50\,k\Omega$, and skin preparation is hardly needed. Occasionally the forehead may be the last site in which degradation occurs in the case of severe disability and degenerative diseases. For instance, ALS and MD (Motor Disability) often allow eyes to move dully though oculomotor neurons and ocular muscles cannot precisely control the focus. Among the bio signals measured on the forehead, the one that is most suitable to a user or the one of which effectivity is highest should be used to the control input signal.

2.2.2 Signal-Inputting Unit

As the bio potential, measured on the scalp by a brainwave sensor, is very minute signal of several microvolts, it should be amplified by 10000 times in maximum. In such a case, the voltage increases from 0 to 5V. The bio potential of the scalp is inputted into an

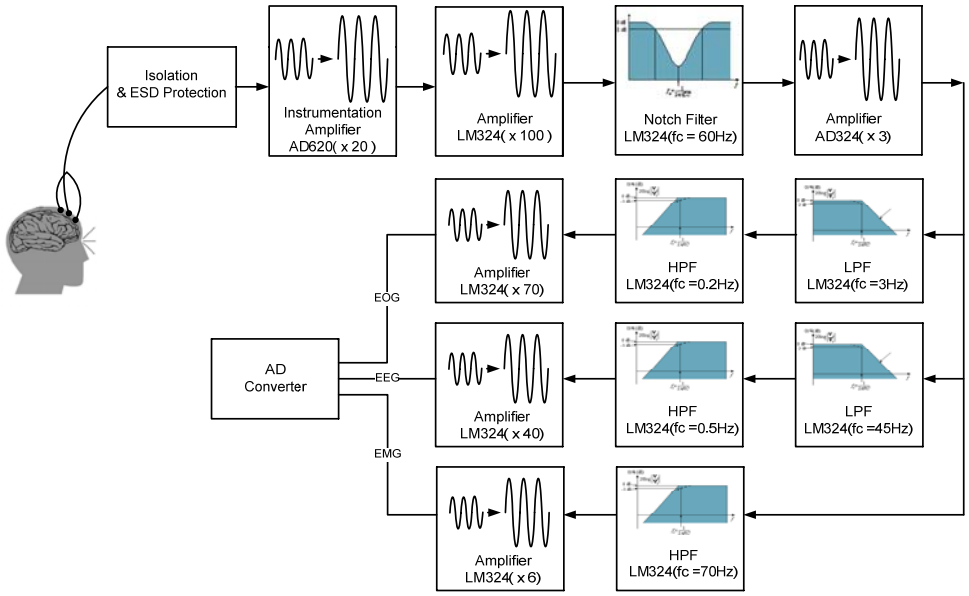

Fig.2 Amplifying and filtering of bio-potentials

A/D converter by passing through a shielding circuit, amplification, filtration and amplification in order. Fig.2 shows that process. Input signals are basically filtered at hardware according to frequency band in order to minimize the calculative load of software. The signal inputted from the scalp is passed through a shielding circuit and an ESD(Electrostatic Discharge Protection) circuit so as to protect the device from static electricity and to remove noises. The signal, passed through a shielding circuit, is primarily amplified through a differential amplification circuit. In this system, Analog Devices' AD620 model was used. The signal, which was primarily amplified, was secondarily amplified by using the LM324 amplifier. This system was so designed that the low amplification factor can be taken at the front end and the high amplification factor can be taken at the after end. Bio potential is amplified by approximately 2000 times by passing through the primary and the secondary amplification circuit. A notch filter removes the noise of 60Hz generated from the measurer and the human body at the amplified signal. The signal, passed through the notch filter, is amplified to some extent and is divided into 3 channels. As shown in Fig.2, a signal is filtered in the frequency band corresponding to EOG, EEG and EMG, passing through LPF and HPF. The EOG signal is between 0.2 and 3Hz, EEG is between 0.5 and 45Hz and EMG is between 70 and 1000Hz. As the signal amplitude is gradually attenuated in process of passing through such filters, the attenuation should be supplemented by the amplifier. Amplification factors are set up as to channel. This is because the raw bio-potentials' amplitude generated from on the forehead are different from signals. The EOG signal ordinarily has the amplitude of several microvolts, but the amplitude of EMG reaches hundreds of microvolts. For this reason, amplification factors were differentiated as to signal type so that the input sizes of A/D converters can be equal to each other. An A/D converter digitizes the analog bio signal with the sampling frequency between 128 and 1KHz.

2.2.3 Digital Signal-Processing Unit

A CPU(Central Processing Unit) processes the bio potential, inputted from an A/D converter, to digital signal and transmits it to a PC. The data, inputted from an A/D converter, correspond to EOG, EMG and EEG signals. Since EOG and EMG signals are bio potentials generated from ocular movement or facial movement, the signal sizes and patterns on time base are important rather than the frequency band. Specifically, the two signals are used to control input by detecting the signals over a reference level. However, EEG signals are divided into alpha wave, beta wave and theta wave in a frequency band on the basis of brainwave theory as well as a specific frequency band may be increased or decreased as to cerebral condition[6]-[8]. This control signal should be the final means for the patients who cannot move

even eyes and facial muscles, their brainwaves should be used to the control input signal under specific situations such as rest, concentration, tension, etc. Our system does not get EEG signals over all the scalp, but takes EEG signals only by the electrode on the forehead. In that case, we cannot the spatial pattern analysis that finds out a correlation over all brain, so we should use only EEG Signals on the scalp(It goes without mentioning that the signal of the frontal lobe is strongest). EEG signals are characterized at a frequency band, not a time domain. Thus, the temporal data is converted into the frequency-band data by Fourier transform. Successive data is converted into by a regular sampling time at an A/D converter, and it becomes discrete data. The operating process should be minimized so that the real-time system can be realized, and FFT algorithm should be used to do this real time process.

3 Experiment Result

3.1 Results of Simulation

The voltage of the frequency band, which was measured at the front and the after end of the hardware configuration's notch filter made out in this study, was simulated by using Pspice. Fig.3 shows its waveform. A band rejection occurred in the range of 60Hz. Likewise, the amplification factors of the frequency bands of EOG, EEG and EMG were simulated. Fig.4 shows their waveforms. They are the values measured the input terminals of an A/D converter after being passed through an amplifier and a band-pass filter. signals were amplified only at the frequency bands corresponding to respective signals. Consequently, input signals on a real hardware will be separated by respective frequencies.

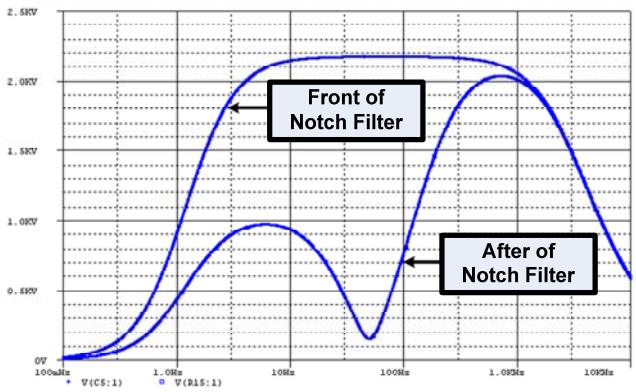

Fig.3 Simulation of the designed notch filter

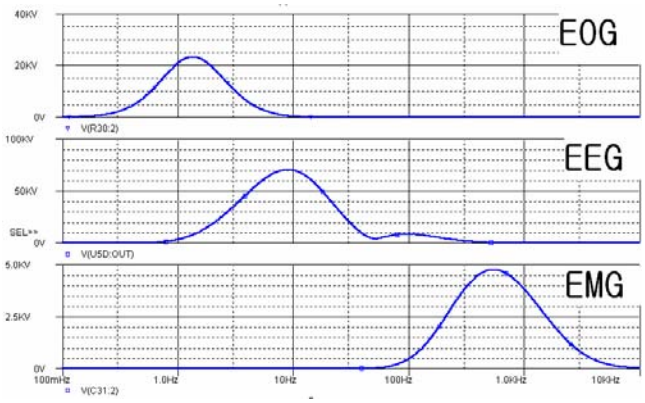

Fig.4 Simulation of amplified signals

3.2 Real Waveforms

Fig.5 shows the brainwave that has only just passed through AD620 differential amplifier; that is the waveform before being separated as to frequency. its amplitude is as low as 20mV though it was amplified twenty times as shown in Fig.2. In case EOG, EMG and EEG signals, shown in Fig.5, are separated as to frequency, they are turned into the waveforms shown in Fig.6~Fig.8. Signals were separated as to respective frequencies by passing through an amplifier and a filter in the hardware made out in this study. Fig.6, 7 and 8 show the signals captured by using an oscilloscope. Fig.6 shows the EMG signal of which frequency band is between 70 and 1KHz. The signals, shown in the middle of the scope, are the waveforms generated when a subject moves facial muscles. Fig.7 shows the EOG waveform between 0.1 and 3Hz. This waveform is generated by moving left and right eyes. Fig.8 shows the EEG signal of which frequency band is between 0.5 and 45Hz. This signal is converted into significant signals such as alpha wave, beta wave and otherwise through frequency conversion.

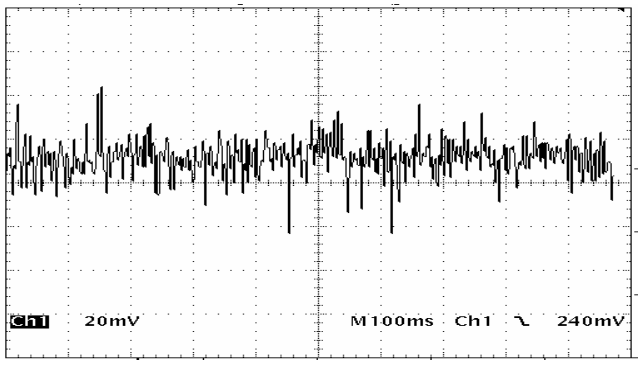

Fig.5 Brain-wave before dividing

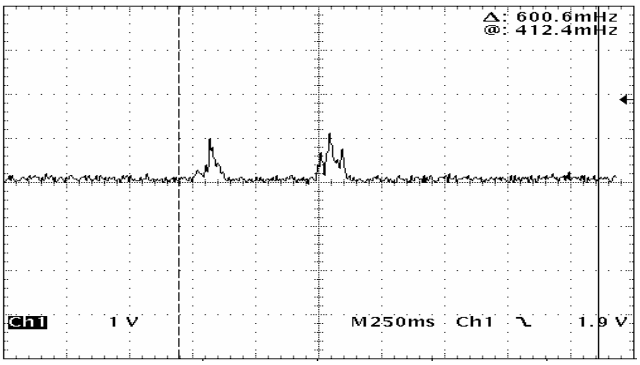

Fig.6 EMG signal(70~1KHz)

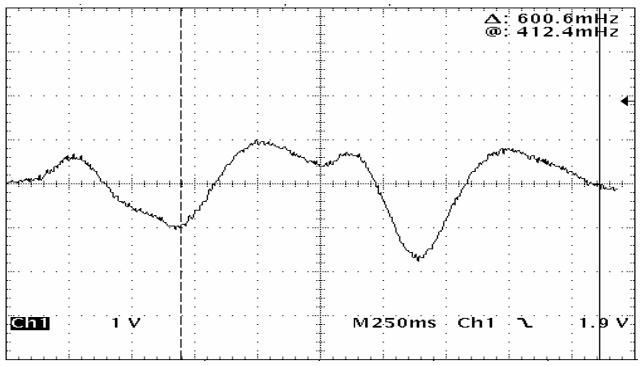

Fig.7 EOG signal(0.1~ 3Hz)

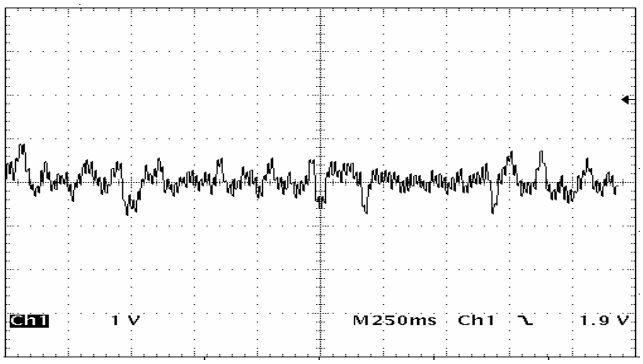

Fig.8 EEG signal(0.5~45Hz)

3.3 EEG Signal Analysis

Fig.9 shows a process of analyzing the EEG signal. The above window shows the waveform of EEG input signal. The signal, passed through a sampling process as to sampling frequency, is updated. That is a kind of scope that displays the input signal every one second. The inputted signal is converted into frequency signal every 0.1 second, by FFT. In case input sampling frequency is 100Hz, the output frequency is converted

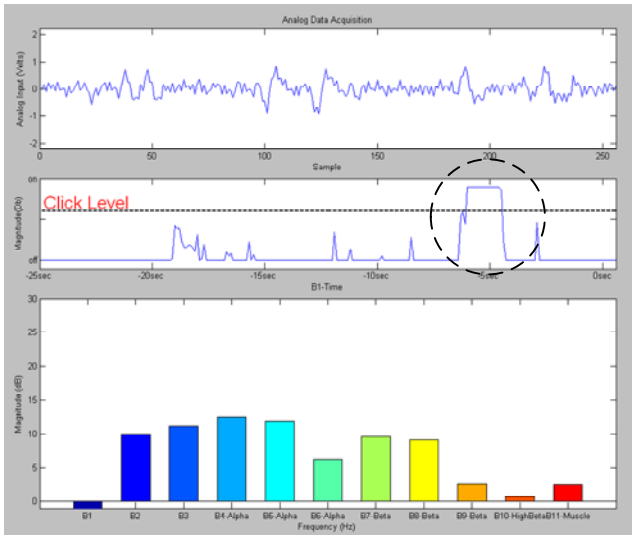

Fig.9 EEG Click test

into the band between 0 and 50Hz. With regard to the result of FFT, its size should be calculated by power spectrum decibel. This is to evaluate a size of the frequency component in the brain on successive time-series input signals, and a specific frequencysize is different from cerebral conditions. The data in the converted frequency band were divided into 11 parts from B1 to B11. The lowest window shows the divided data. Frequency band is based on the brainwave theory, and they are ordinarily divided into delta(0.5~4Hz), theta(4~7Hz), alpha(8~13Hz), beta(14~30Hz) and muscular frequency(30~45Hz)[6]-[8]. In the present study, alpha wave and beta wave were divided more minutely. On this wise, subjects will intentionally try to generate regular brainwaves in that they can personally observe their own brainwaves. In addition, they will be able to control their brainwaves over time. Among the signals in the divided frequency bands between B1 and B11, the signal suitable to the control input should be selected in advance. In the middle window, the selected signals are displayed in real-time. In Fig.9, the signal of B1 was used to the control input signal; the waveform of B1 is remarkably influenced by nictitation. The slight signal in the middle of the scope, which does not exceed the click level, is generated whenever a subject nicitates eyes. In case a subject intentionally nicitates eyes, the signal exceeds the click level as shown in the Fig.9. In case a subject cannot move eyes and facial muscles, alpha wave (B4~B5) or beta wave (B7~B10) should be used to generate the control input signal.

4. Conclusion

The present study proved that EMG, EOG and EEG signals can be respectively to the control input signal through separation. This system is expected to realize the computer access control because the signal, which is most suitable to each patient's condition and situation, can be selectively used. Regarding real experiments, normal subjects, who can freely move their eyes or facial muscles, were selected. Success rate was remarkably improved after repetitive training; it is considered that severely motor disabled will improve the success rate to practical level if they are repetitively trained as well as its effectiveness will be more increased in case of paying due regard to their circumstances, by reason that their interests in this device will be keener as compared with normal humans because this device may be their only communicable device.

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