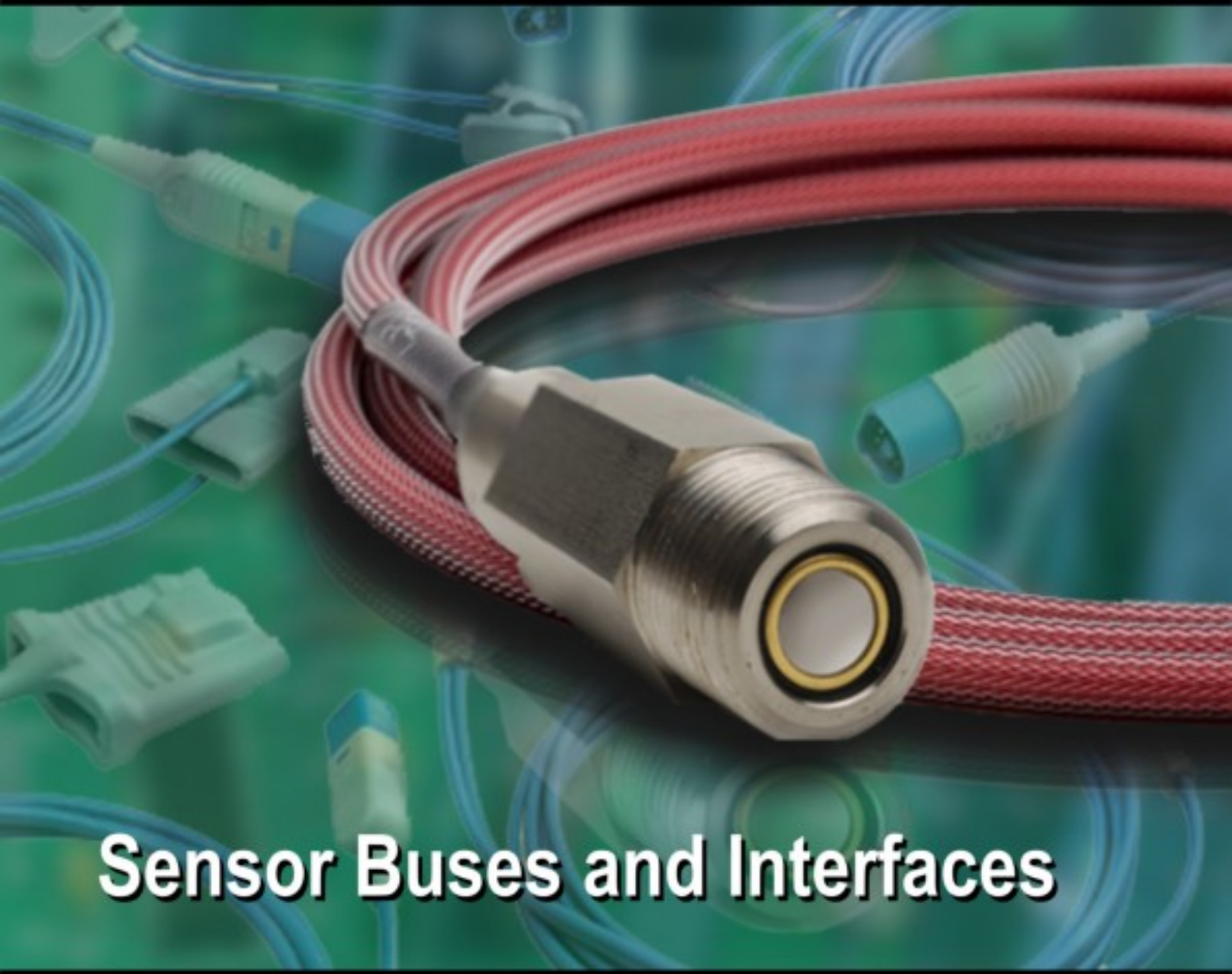
ISSN 1726-5749

# SENSORS & TRANSDUCERS

vol. 92
5/08



## Sensor Buses and Interfaces

International Frequency Sensor Association Publishing

IFSA

# Sensors & Transducers

Volume 92
Issue 5
May 2008

www.sensorsportal.com

ISSN 1726-5479

Sensors & Transducers Journal (ISSN 1726-5479) is a peer review international journal published monthly online by International Frequency Sensor Association (IFSA).
Available in electronic and CD-ROM. 

Sensors & Transducers Journal

# Contents

Volume 92
Issue 5
May 2008

www.sensorsportal.com

ISSN 1726-5479

## Research Articles

Authors are encouraged to submit article in MS Word (doc) and Acrobat (pdf) formats by e-mail: editor@sensorsportal.com
Please visit journal's webpage with preparation instructions: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm

*Sensors & Transducers Journal, Vol. 92, Issue 5, May 2008, pp. 144-151*

www.sensorsportal.com

**Sensors & Transducers**

**ISSN 1726-5479**

*http://www.sensorsportal.com*

# Active Bio-Sensor System, Compatible with Arm Muscle Movement or Blinking Signals in BCI Application

**Saeid Mehrkanoon, Mahmoud Moghavvemi**
Center for research in applied electronics (CRAE)
Dept. of Electrical and Electronic Engineering, University of Malaya,
50603 Kuala Lumpur, Malaysia
E-mail: mehrkanoon@perdana.um.edu.my, mahmoud@um.edu.my

*Received: 12 April 2008 /Accepted: 20 May 2008 /Published: 26 May 2008*

**Abstract:** This paper addresses a bionic active sensor system for the BCI application. Proposed system involves analog and digital parts. Two types of accurate sensors are used to pickup the blinking and muscle movement signals. A precision micro-power instrumentation amplifier with the adjustable gain, a sixth order low pass active filter with cutoff frequency 0.1 Hz, and a sixth order band pas filter with the bandwidth of 2-6 Hz are constructed to provide the clean blinking and arm muscle movement signals. TMS320C25 DSP processor is used for independent and unique command signals which are prepared for BCI application by a power amplifier and driver. *Copyright © 2008 IFSA.*

**Keywords:** EMG, Active sensor, Instrumentation amplifier, Unique signal, BCI

## 1. Introduction

Eyelid movement generates specific signals which can be picked up from around the eye. The muscles activities generate the signals called ElectroMyoGram (EMG). The EMG signal is a composite of all the muscle fiber action potentials occurring in the muscle(s) underlying the skin. EMG can be picked up from over the skin [1]. For many Brain Computer Interface (BCI) applications and human based control system and interfacing, the unique signals are required for issuing the accurate command. A proper sensor system can provide the accurate signal for BCI system.

In this study the surface arm-EMG and eyelid movement signals are passed through the active bio-sensor system and converted to unique signals. An accurate and flexible active bio-sensor system is proposed for proper communication with eyelid movement and surface EMG. The high performance

analog components and DSP processor are employed by the proposed system to issue the command signals for BCI system.

## 2. Methodology of Bio-Sensor System Design

The block diagram of the proposed system is shown in Fig. 1.

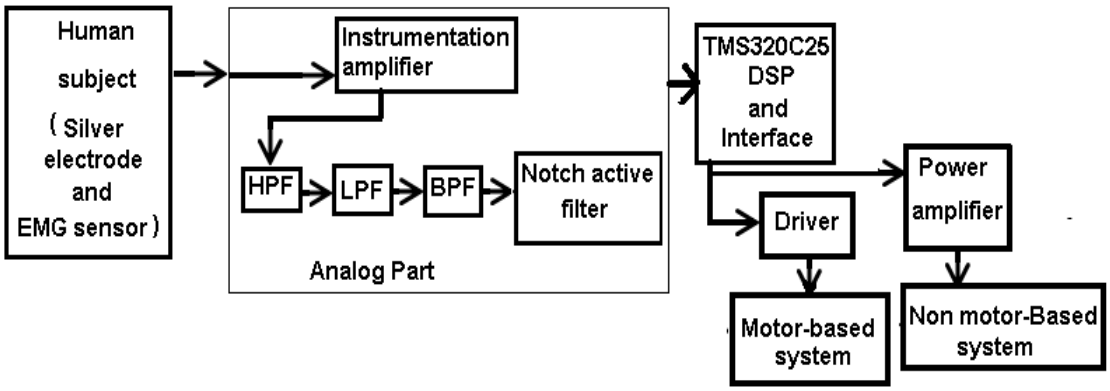



**Fig. 1.** Block diagram of bio-sensor system.

Two points, one above the eye and one over the arm muscle based on only one grounded point located at protuberance of the ear are selected to pick up the eyelid movement and surface EMG signals. The pure silver/silver chloride electrode with specifications of flexible and double protective seal at electrode end is used to pickup the blinking signal [2].

The surface EMG sensor DE-2.1 is applied to collect the EMG and muscle activity signal from over the skin [3]. Table 1 shows the specifications of the employed surface EMG sensor. Due to the high input impedance of the surface EMG sensor no conductive paste and skin preparing gel are required.

**Table 1.** The specification of surface EMG sensor.

| **EMG Sensors** | **DE-2.1** |
|---|---|
| Type | Single Differential |
| **Mechanical** | |
| Number of Contacts | 2 |
| Contact Material | 99.9% Ag |
| Case Material | Polycarbonate |
| Connector | Hypertronics D04 |
| **Electrical** | |
| Preamplifier Gain | 10 V/V ±1% |
| Bandwidth | open |
| Noise | 1.2uV (RMS, R.T.I.) |
| CMRR (60/10 Hz) | -92 dB (typical) |
| Power Consumption | 20 mW (typical) |
| Input Impedance | $>10^{15}\Omega$ //0.2pF |

Fig. 2 shows the silver electrode and surface EMG sensors.

(a) (b)

**Fig. 2.** a) Silver/silver chloride electrode, b) DE-2.1 surface EMG sensor.

Several types of surface EMG and silver electrodes can be found in ref [4]. The precision low power instrumentation amplifier with the adjustable gain between 100-10,000 v/v is applied to amplify the signal. The most important specifications of the instrumentation amplifier include:

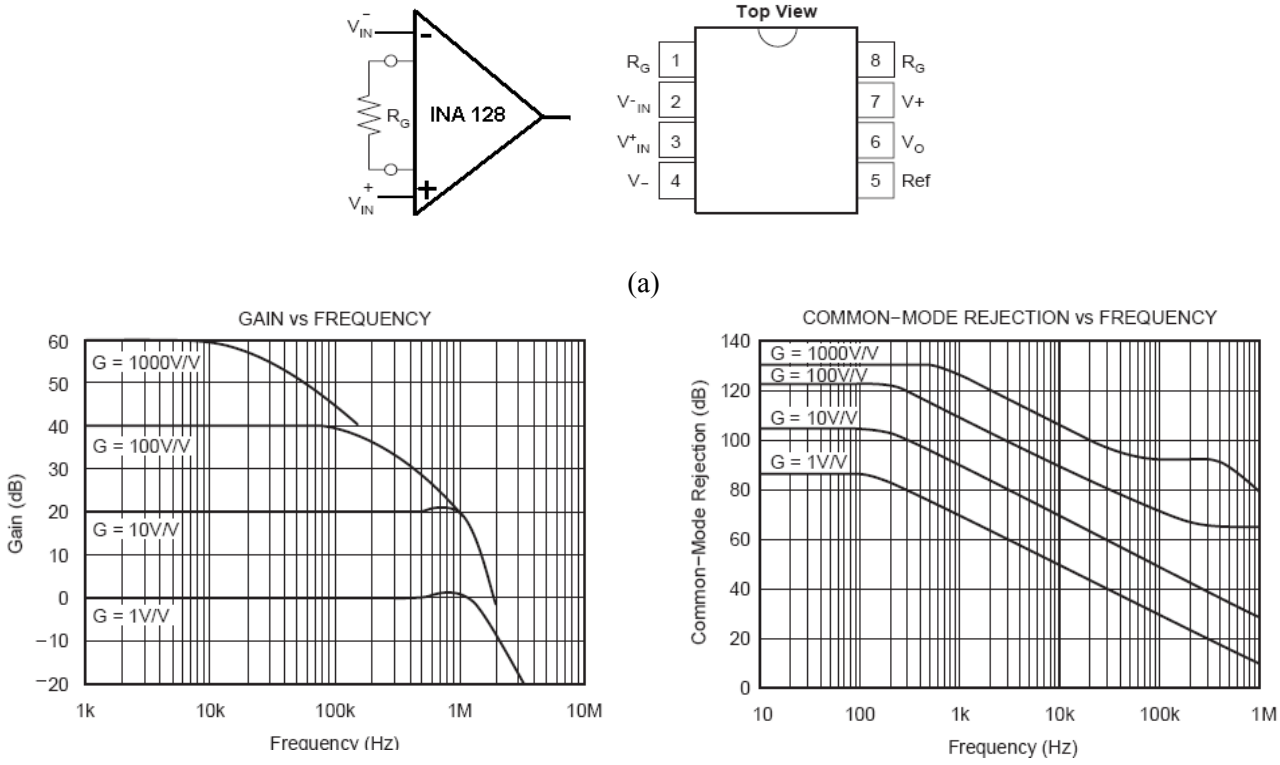
1- low offset voltage: 50 $\mu v$

2- high CMRR 120dB at gain $\geq$ 100

3- wide rang supply $\pm 2.5v$ to $\pm 18v$

4- Two over-voltage protectors up to $\pm 40v$

The input impedance of the instrumentation amplifier is extremely high –approximately $10^{10}\Omega$. Hence, the input bias current changes very little with varying input voltage. Fig. 3 illustrates a) the INA128 instrumentation amplifier and pin configuration, b) gain-frequency response, and c) CMR–frequency response [5].




(a)

(b) (c)

**Fig. 3.** a) Configuration of INA128 instrumentation amplifier; b) gain-frequency response; c) CMR-frequency response.

A third order high pass filter with -3dB frequency of 0.01 Hz is used to remove DC offsets. A sixth order low pass active filter with cutoff frequency 0.1 Hz is employed to pass the blinking signal. Fig. 4 represents the magnitude-frequency response of the employed low pass filter.

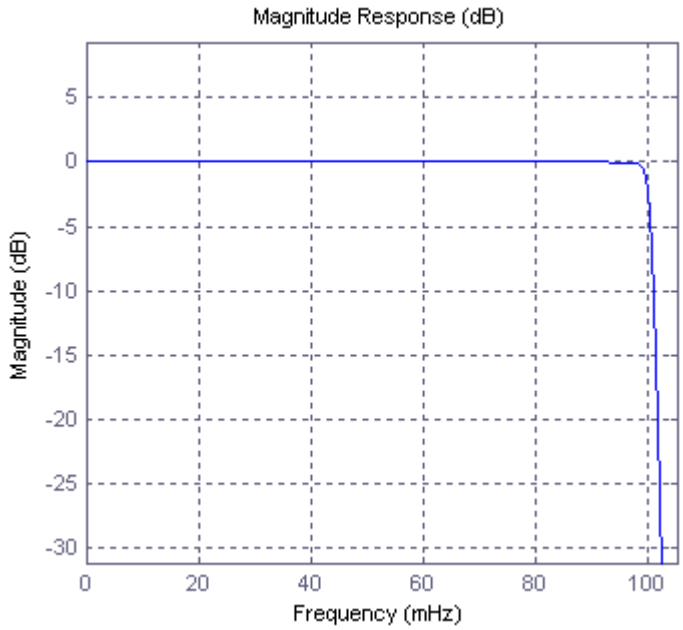



**Fig. 4.** Magnitude-frequency response of low pass filter.

To extract the pure muscle activity signal from EMG, a sixth order band pass active filter with the bandwidth of 2-6 Hz is applied.

Fig. 5 shows the magnitude-frequency response of the employed filter.

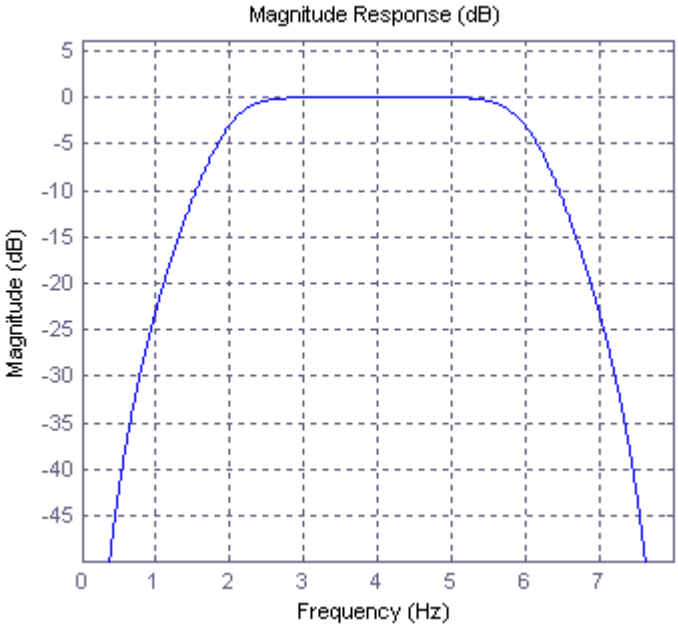
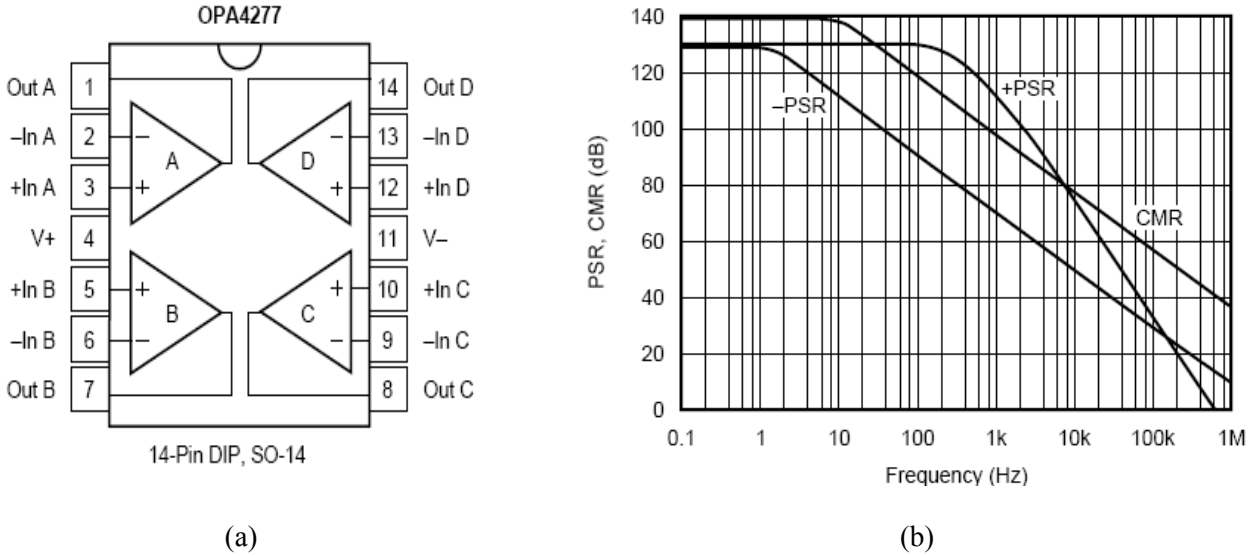



**Fig. 5.** Magnitude-frequency response.

A high precision OPA-4277 operational amplifier with the specifications of ultra low offset voltage $10\mu v$, high CMRR $140dB$ is used in the design of all the proposed active filters. The employed op-amps are free from phase inversion and over load problems. They are stable in unity gain and provide excellent dynamic behavior over a wide range of load conditions [5]. Fig. 6 illustrates a) the OPA-4277 and b) CMR-frequency response.




(a) (b)

**Fig. 6.** a) OPA-4277 configuration pins; b) CMR-frequency response.

In digital part, the TMS320C25 fix-point DSP with the minimum external peripheral devices employs the blinking and muscle activity signals to process and issue the command pulse. A few important features of employed DSP are [6]:

1- 4k- word on-chip program ROM and 128k program memory space
2- 32bit ALU and on-chip timer for control operations
3- On-chip full duplex serial port and $16\times16$ bit parallel port.
4- Single supply 5v.

Fig. 7 shows the block diagram of DSP TMS320C25.

Power spectrum analysis and FFT-based algorithm are applied for feature extraction from blinking and muscle activity signals. The digital Butterworth IIR low pass and band pass filters with the length of 32 are employed by the algorithm to extract the features and issue the unique signals to the power amplifier and driver. The driver circuit provides a proper signal to drive the motor-based robot system for BCI application. It uses the issued command signals generated by DSP or microcontroller to run the electromechanical system [7, 8].

Several driver circuits such as ULN2003 and L293D can be connected to DSP processor. In this study the stepper motor driver UC3717A is used. The UC3717A has been modified to supply higher winding current. It provides more reliable thermal protection and improved efficiency by providing integrated bootstrap circuit to lower recirculation saturation voltages. Fig. 8 represents the block diagram of the UC3717A. The power amplifier circuit is employed to amplify the DSP-based command signals for non-motor based system in BCI or other applications.

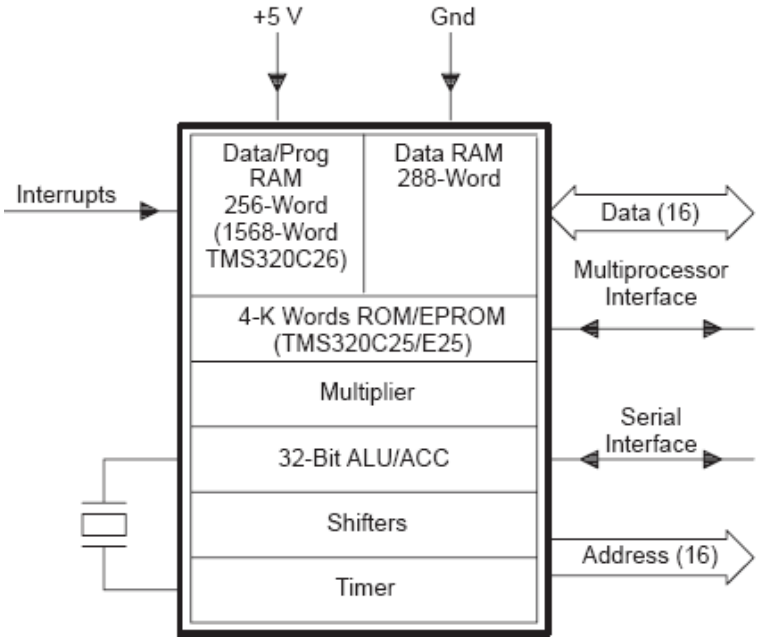



**Fig. 7.** Block diagram of TMS320C25.

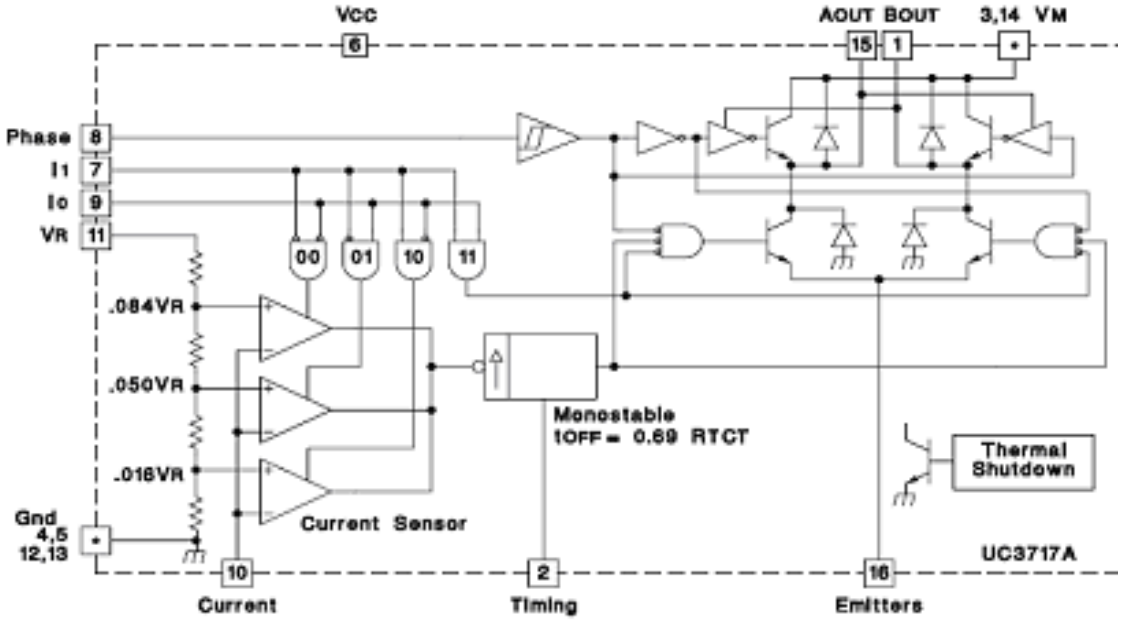



**Fig. 8.** UC3717A stepper motor driver.

## 3. Result and Discussion

Observed blinking and arm muscle movement signals are shown in Fig. 9. The amplitude of blinking and arm muscle signals after amplification are approximately $\pm 2v$ and $\pm 4v$, respectively. Several negative and positive peaked pulses shown in Fig. 9 a) are generated when the eyelid goes down and up. Fast eyelid movement signals are shown in between 8-10 (sec). Several positive and negative peaked pulses shown in between 2-4 (sec) and 4-6 (sec) are produced by arm muscle movements.

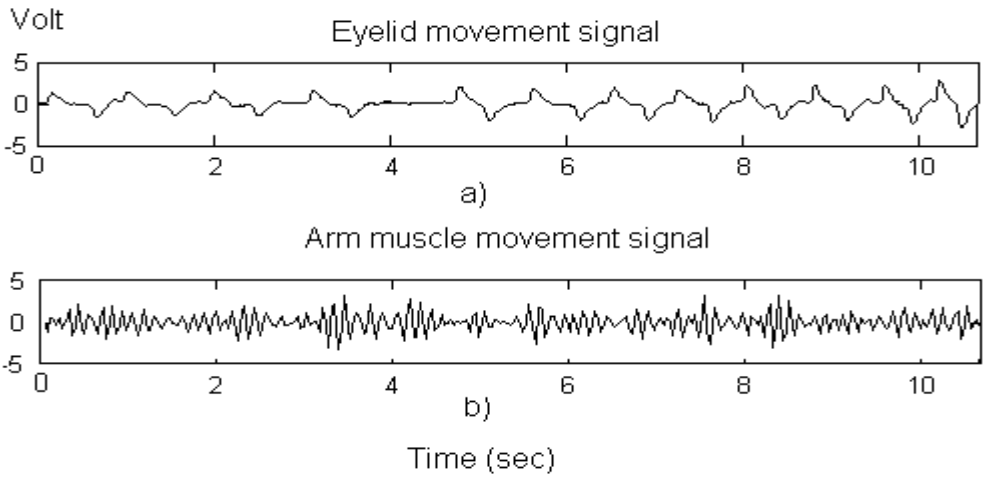



**Fig. 9.** a) Obtained blinking signal; b) Arm muscle movement semi periodic signal.

Fig. 10 a) represents a portion of the several extracted positive and unique waves (command) from eyelid movement signal. Fig. 10 b) shows a portion of the command signals obtained from arm muscle activity signal.

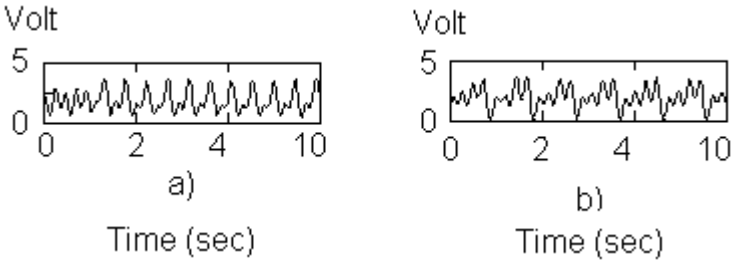



**Fig. 10.** a) Unique command blinking signal; b) Unique command arm muscle movement signal.

## 4. Conclusion

The active bio-sensor system based on implementation of silver/silver chloride electrode and surface EMG sensor is proposed in this paper. The proposed bio-sensor system picks up the blinking and arm muscle movement signals to issue the unique command (signals) for BCI systems. Analog part of the proposed system provides clean eyelid movement and arm muscle activity signals for digital signal processing part. TMS320C25 DSP processor is employed to make the digital filters and generate the unique signals based on FFT and power spectrum analysis algorithm. The results show the unique commands signals are produced by the active bio-sensor system.

## References

[1]. Dieter Bingemann, Analysis of 'blinking' or 'hopping' single molecule signals with a limited number of transitions, *Chemical Physics Letters,* 433, 2006, pp. 234–238.
[2]. Fernandez M., Pallas-Areny R., Ag–AgCl electrode noise in high-resolution ECG measurements, *Biomed. Instrum. Technol.*, 2000, 34, pp. 125–130.
[3]. S. H. Roy G. De Luca, et al., Electro-mechanical stability of surface EMG sensors, *Med. Bio. Eng. Comput.*, 2007, 45, pp. 447–457.
[4]. http://www.biometricsltd.com

[5]. Dobrev D, Daskalov I, Two-electrode biopotential amplifier with current-driven inputs, *Med. Biol. Eng. Comp.,* 2002, 40, pp. 122–127.
[6]. www.ti.com/digital signal processor.
[7]. Remmerie. G, Cox. P, et al. Driver ICs elevate design of stepper-moter control, *Power Electronics Technology,* Vol. 33, Issue 8, 2007, pp. 14-20.
[8]. V. Marano, D. Arrigo, Novel fully integrated 65W stepper motor driver IC, *International Symposium on Power Electronics, Electrical Drives, Automation and Motion, SPEEDAM*, 2006, 24, pp. 12-16.

---

**Sensors & Transducers Journal**

# Guide for Contributors

## Aims and Scope

*Sensors & Transducers Journal (ISSN 1726-5479)* provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

## Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

## Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 6-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: http://www.sensorsportal.com/HTML/DIGEST/Submition.htm Authors must follow the instructions strictly when submitting their manuscripts.

## Advertising Information

Advertising orders and enquires may be sent to sales@sensorsportal.com Please download also our media kit: http://www.sensorsportal.com/DOWNLOADS/Media_Kit_2008.pdf