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Feature Extraction cum Frequency Analysis System for Facial Surface Electromyography Signals Based Human Speech Recognition

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Abstract: Surface Electromyography (SEMG) signal processing is being applied for diagnosis of neuromuscular disorders, sports medicine and as control signal in physiological rehabilitation. It can also be applied for detection and generation of spoken contents in human speech. Collection of important facial EMG signals as per human's own natural voice pattern and generation of its database is a pending task before researchers. Such a database can empower and enable them to invent natural voice like speech for every individual as like his/her own voice. This paper proposes a novel invention that is able to extract features by capture, record and filter human speech related facial muscle signals. A two channel SEMG system has been developed by us for data collection from articulator muscles of the face by capturing signals using two pairs of electrodes attached to important facial muscle sto record EMG patterns corresponding to spoken alphabets. These signals, after due pre amplification, filtering and denoising have been processed for extracting the features using Lab VIEW. As pilot study on English alphabets representing glottal, nasal, fricative, approximant, plosive and vowel type sounds. The facial EMG signals generated have been demonstrated using this system. This paper highlights their two features, i.e. peak frequency and dominant frequencies under each type of sound for respective alphabet have been extracted.
Keywords: SEMG, EMG, human speech, data acquisition, Bio signal processing, frequency spectrum, speech rehabilitation.

I. INTRODUCTION

Electronic generation of human speech sounding like individual's own natural voice is one of the major challenges before researchers. No systematic data or scientific studies related to human speech producing muscular activity verses natural spoken languages are available. Muscular activities are resultant of application of electrical potential under command and control of human brain via nervous system, technically called action potential. Humans generate speech by selective control of muscles on their faces in conjunction with the larynx, glottis, vocal cord, tongue, pharynx, etc. The major muscles that get activated to generate speech on the face of a person are zygomaticus major and minor, levator anguli oris, Masseter, and orbicularis oris (Fig. 1)

Non invasive recording of electrical current produced by ionic flow across muscle fiber membranes and transmitted through intervening tissuesat specific location on skin due to muscular activity is called surface Electromyography (SEMG).

The basic entity of a muscle is motor unit that generates a motor unit action potential (MUAP) when activated. In a muscular movement, several motor units are activated to generate motor unit action potential trains (MUAPT) that are superimposed to form the electro my ographic (EMG) signal [1].

The collection (database) of EMG signals emanated from the muscles using electrodes can serve as a useful tool in speech rehabilitation, diagnosis/treatment of many neuromuscular problems, engineering and medical research. The concept of myoelectric control using EMG signals from contracting muscles was proposed in the late 1940s and that was applied first to manipulate an artificial hand [1]. The technique for exploiting facial muscles to synthesize artificial speech is still in research stage. Facial SEMG signals are quite weak signals (µV to low mV) and are also of very low frequency (up to 500 Hz) and therefore prone to unwanted noises. Being very low frequency, it needs careful processing to make it suitable for any health care applications.
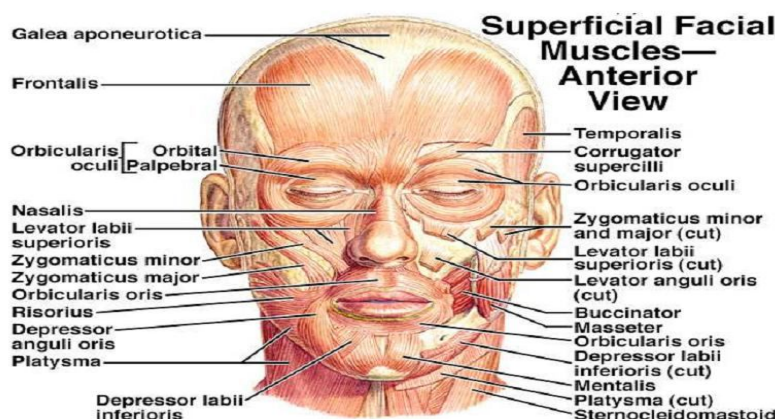
Fig. 1 Muscles of the Face

Signal amplification and filtering plays a critical role in EMG based practical applications. Main challenge for such systems is to extract maximum true information and features out of the physiological EMG signals despite presence of artifacts and noise removal by filter circuits. The major functions of amplification and filtering process are to maximize signal to noise ratio and the minimize artifacts, noise and distortions present within the signal bandwidth of interest (typically 0-500 Hz). This paper presents a complete setup to pick up speech related SEMG signals. It makes use of differential amplification technique and an active band pass filter with Sallen Key architecture. [2]. Analog EMG signal scan be captured using small pre gelled Ag/AgCl electrodes and National Instrument's USB-6009 hardware. Using specialized VIs (of LabVIEW), captured signals are further processed and analyzed. Subsequent sections of this paper elaborate the design, important parameters and a pilot test carried by speaking English letters. The analysis of the results of pilot test demonstrates and validates that the amplification, filtering circuit in conjunction with VIs of Lab VIEW could match with the human speech spoken during experiment test cases.

II.   EMG SIGNAL AND THE NOISES

The amplitude of the EMG signal shows stochastic (random) nature and Gaussian distribution function can appropriately represent it. The signal amplitude has a range from 0 to 6 mV (peak-to-peak) or 0 to 1.5 mV (r.m.s.), while overall energy of the signal lies in the frequency band of 0 to 500 Hz, the dominant energy concentrates around 50-150 Hz range [3]. Outside this band, the electrical noise level dominates the signal and that indicate any EMG signal acquisition process gets easily influenced by noise. Such noise could be attributed to electronic and other parts used for signal detection and recording, the ambient noise from the electromagnetic and power line radiation in the environment, the motion artifacts with electrical signals (mainly within 0-20 Hz range) from the electrode-skin interface and from movement of the cable connecting the electrode to the amplifier. Inherent instability of the EMG signal with unstable components in 0-20 Hz range is attributed to the quasi-random nature of the firing rate of the muscular motor units [3].

Core characteristics of SEMG signals (amplitude, time and frequency) are influenced by the anatomical and physiological characteristics of muscles, the control mechanism of the nervous system, and the instrumentation involved. Multiple factors can have significant effect during capture of EMG signal, and therefore can adversely affect determination of feature extraction such as the timing and intensity of muscle contraction, the distance from the electrode to the target muscle, the amount of adipose tissue between the skin and the muscle, the properties of the electrode and the amplifier, and the contact between the skin and the electrode [4]. The articulatory muscles of face are engaged in the process of speech production. However, it is still a challenge for researchers to model and control facial movement. The research in this paper is an attempt to validate such a hypothesis i.e. relationship in facial muscles EMG signals with that of spoken speech (letters).

III.   ELECTRODES AND PREAMPLIFIER

The quality of an EMG signal acquired by the electrodes (from the skin surface)is not merely dependent on the properties of the amplifiers but also on multiple factors related to electrodes, i.e. their size, type, placement. SEMG being a weak signal (tens to thousands μV), necessitates use of high gain amplifiers (gain in thousands). Fig. 2 illustrates schematic order of the amplification and filtering stages implemented for the system developed by us. The first stage i.e. preamplifier is closest to the electrodes and it must have high common mode rejection ratio (CMRR), high input impedance, a strong direct current (DC) signal suppression and be placed

close to the signal source. The output of preamplifier is fed to a band pass filter before amplifying it further. Finaloutput signal (post amplification and filtering) is fed to an analog-digital converter (ADC).

| SEMG Electrodes | → | Preamplifier Stage | → | High Pass Filter | → | Low Pass Filter | → | Amplifier Stage | → To ADC |
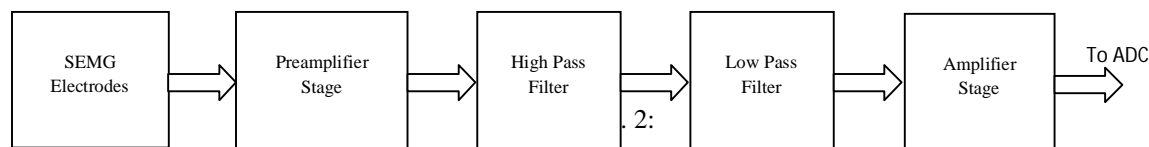
Amplification and filtering process for SEMG

A. Electrodes

The quality and the design of the electrodes directly and immediately affect the quality of capture of the EMG signals. Ability of an electrode in terms of its skin electrical contact and its proper placement is of utmost importance. Surface electrodes being non invasive have been preferred for this pilot study. They are economic, size effective and commonly available, and enable easy change of subject (human) for testing. Fig. 3shows the electrodes that can be used for capture of the signals from the facial muscles. Under the pilot study MLGST-07 (manufactured by Medico Electrodes International Ltd) pre gelled Ag/AgCl electrodes with a conducting diameter of 16 mm and adhesive diameter of 27 mm by 35 mm have been used.

Fig. 3: Typical Surface EMG Electrodes

B. Preamplifier

Fig. 4 depicts a schematic circuit of the preamplifier we have used. It uses Texas Instruments' instrumentation amplifier INA128 and an operational amplifier OPA2604 as reference-driven pre amplifier and a shielding-driven circuit. INA128 is a low power, general purpose instrumentation amplifier offering excellent accuracy with very low offset voltage, drift and high common-mode rejection [5]. The gain, G,of this amplifier is governed by

$$G = 1 + \frac{50\ K\Omega}{R_G} \qquad (1)$$

where, RG is an external resistor.

EMG signal picked using electrodes is fed into the differential input pins of INA128. R_1 and R_2 comprise the gain resister R_G. A signal from the midpoint of R_1 and $R_2$is fed into OPA2604 to provide a guarding potential and a reference potential. Overall gain of about 343 has been applied to weak EMG signals by employing a preamplifier circuit. We could maintain the stability and could avoid saturating the subsequent amplifier with this gain.
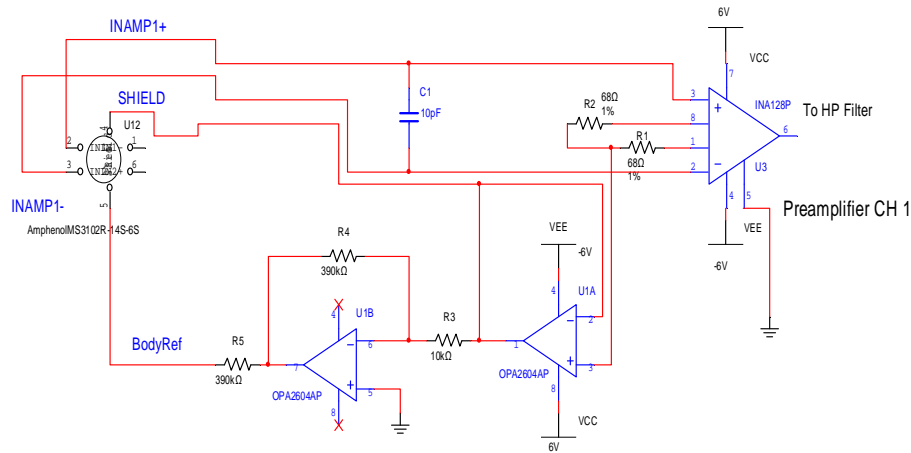
Fig.4: Reference and shielding-driven pre amplifier

IV. BAND PASS FILTER

After preamplification, a band pass filter circuit is applied to restrict the useful signal within 10 to 500 Hz range.Like others, we used second order Sallen Key highpass filterwith cut off frequency of 10 Hz followed by asecond order Sallen Key low passfilter with cut off frequency 500 Hz [6, 7].

The corner frequency and the pass band gain of the second order Sallen Key high pass filter (Fig. 5) have been calculated using

$$f_c = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \qquad (2)$$

$$G_{pass} = 1 + \frac{R_4}{R_3} \qquad (3)$$

wheref_c is the corner frequency andG_{pass} is the passband gain.

Since the noises coupled into the circuitry from electromagnetic radiation are likely more towards higher frequency band, a second order Sallen Key low pass filter follows the high pass filter stage as shown in Fig. 5. Like others we used the corner frequency of the second order low pass filter as 500 Hz and the roll off rate -20dB/Decade [8].
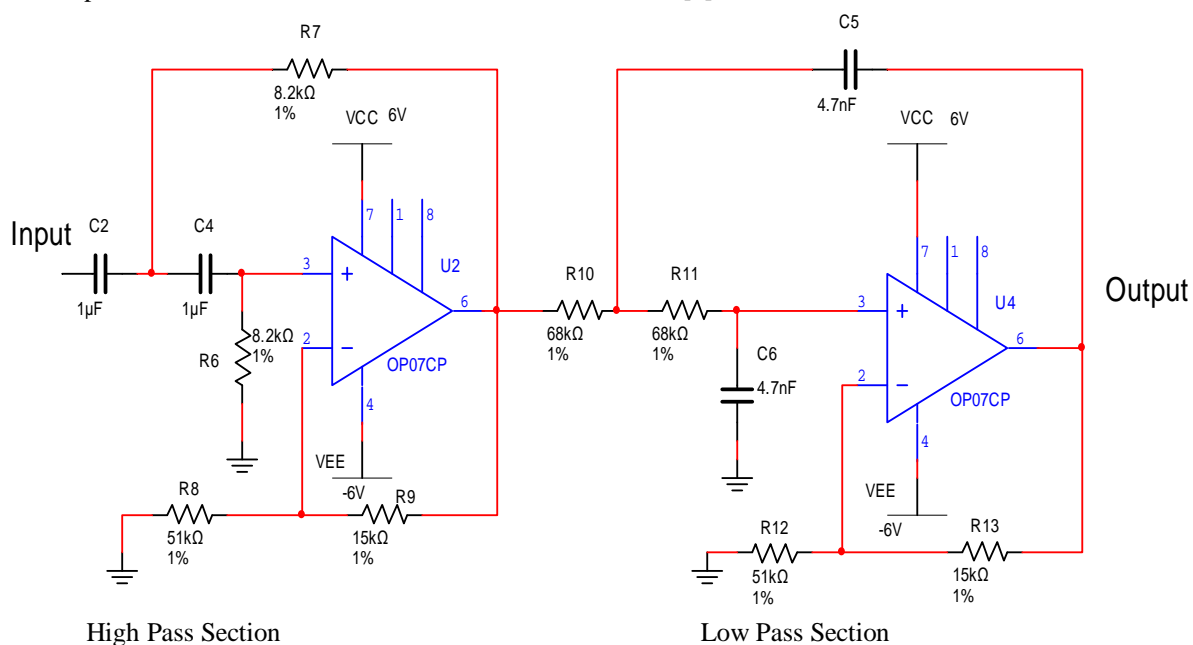

Fig. 5: Schematic of secondorder SallenKey active filters

(Corner frequency of 20 Hz & 500 Hz and a roll off rate of -20dB/Decade)

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V. EXPERIMENT

Overall experimental circuit configured is illustrated in Fig. 6 and Fig. 7 shows schematic of the 2 channel SEMG data acquisition. After the electrodes and the pre-amplifier, the filtered signal is amplified and conditioned using USB-6009 DAQ card from National Instrument. The amplified and filtered EMG signal is sampled and recorded using Lab VIEW Biomedical Toolkit. Such a pair of amplified and filtered EMG signals from two muscles forming two channels is fed into differential analog inputs of DAQ card that is connected to computer through USB port. The Biomedical toolkit is used for logging the EMG data. The spectra of the EMG signals are analyzed using LabVIEW.

Fig. 6: Setup for Acquiring Speech Related EMG Signals

The recording of EMG signals is done at the rate five times the highest frequency i.e. at a sampling rate of 2500 Hz. 2500 Hz sampling rate tends to suppress effect of the frequencies above 1000 Hz as well offer reasonable size of the data generated.

A five lead cable with snap type connectors and pre-gelled surface EMG (SEMG) electrodes were used to capture EMG signals using two pairs of electrodes on two facial muscles namely zygomaticus major and levator anguli oris, while the reference electrode is placed at forehead. An inter electrode spacing of 2 cm is maintained[15].
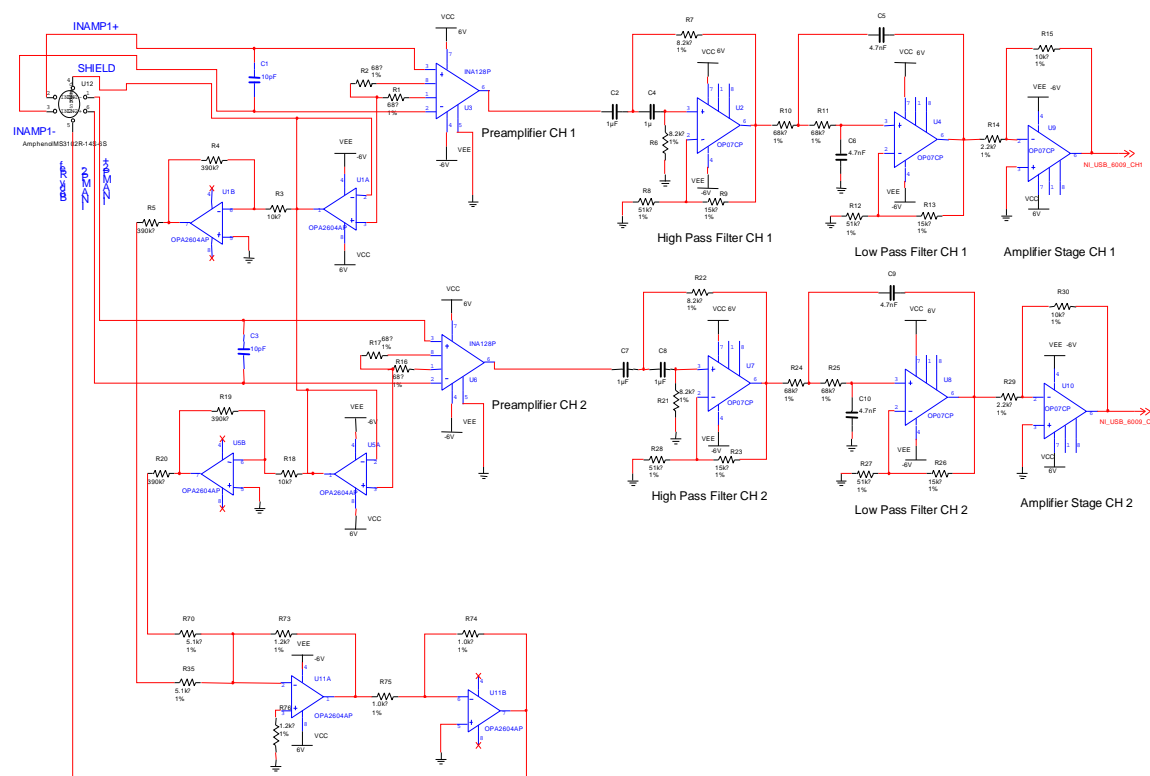
Fig. 7: 2-Channel Circuit for Surface EMG Data Acquisition

Under parameters listed in Table I, the test is performed by collecting SEMG signal samples from a pair of facial muscles viz. zygomaticus major and levator anguli oris corresponding to one utterance each from six main categories of English alphabets i.e. vowel (letter *A*), plosive (letter *P*), fricative (letter *F*), nasal (letter *M*), approximant (letter *W*), and glottal (letter *H*). For each alphabet (A/P/F/M/W/H), the test is repeated twenty times and twenty sets of data are collected. 8000 samples of each test alphabet are recorded at 2500 Hz frequency [9], [12]. The experimental data are stored in data files using Biomedical Toolkit and then transferred intoLabVIEW software where denoising and time-frequency analysis is done. Channel 1 has been used for recording zygomaticus major while channel 2 picks up signals of levator anguli oris muscles on the left side of human face. The recording period is set to be 3.2 seconds but the actual speech is produced (recorded) for less than a second somewhere in mid during 3.2 seconds, as the rest (pre and post actual speech) being silence period.

Table I: Experimental Parameters

| Electrode Placement		Inter electrode spacing	Corner Frequencies		Approximate Circuit Gain	
CH-1	CH-2		High Pass	Low Pass	Pre amplifier	Amplifier
Zygomaticus Major	*Levator Anguli Oris*	2 cm	10 Hz	500 Hz	353	13

VI. DATA ANALYSIS

LabVIEWVIs are used to analyze experimental data, noise removal and to display EMG signal waveforms [10], [11]. The clean signal so obtained is normalized and the amplitude response is performed by FFT. The spectra of both channels for all the test alphabets are plotted. The raw and denoised SEMG signal plots for both the channels for one of the test alphabets, *W*, as obtained are shown under Fig. 8. The plot 8(a) depicts raw EMG, 8(b) show denoised signal, 8(c) draw amplitude response while 8(d) exhibits dominant
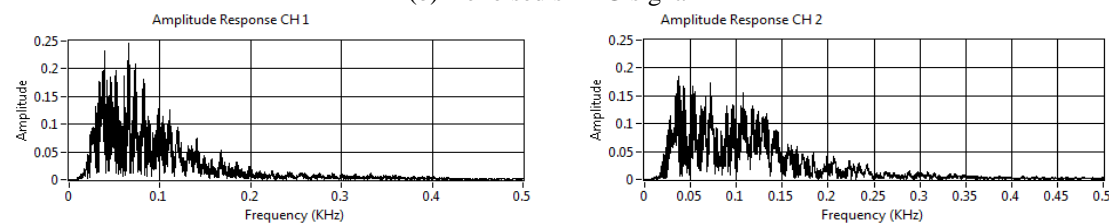
frequency range. The pause period (silence) can also be observed in fig. 8 (b). Fig. 9 shows the amplitude responses of different consonants*("F", "H", "M", and "P")*and vowel "A"similarly.
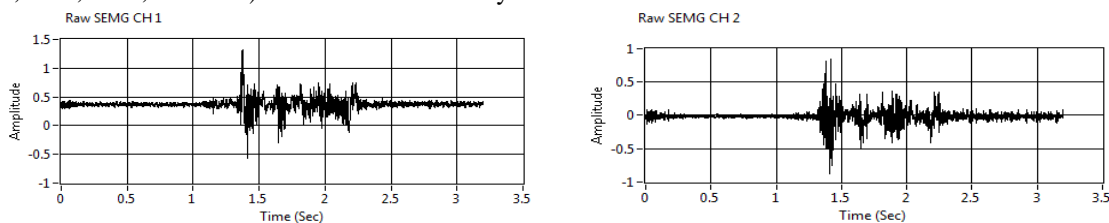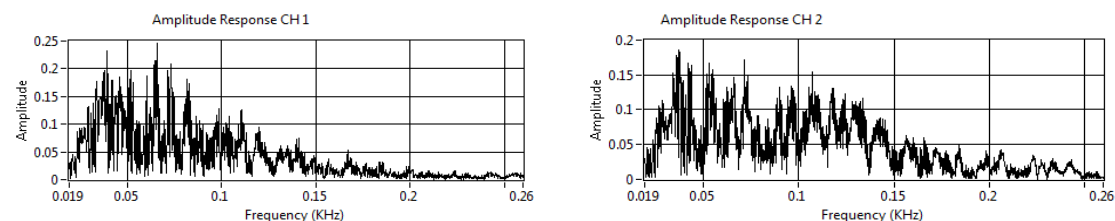

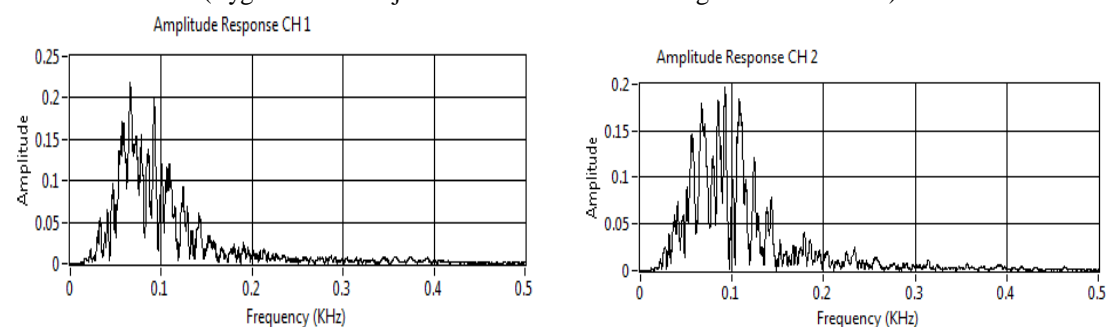(a) Raw sEMG signal with noise
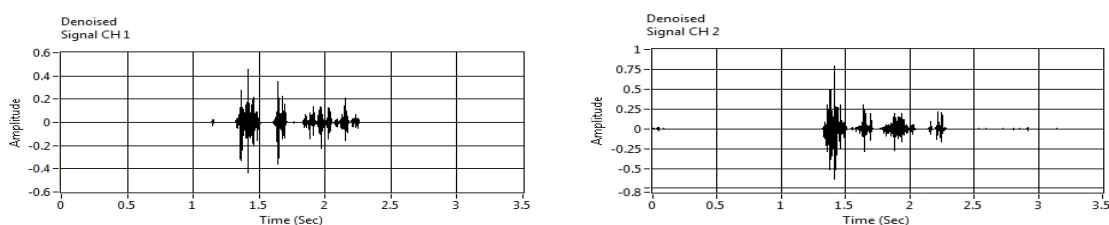
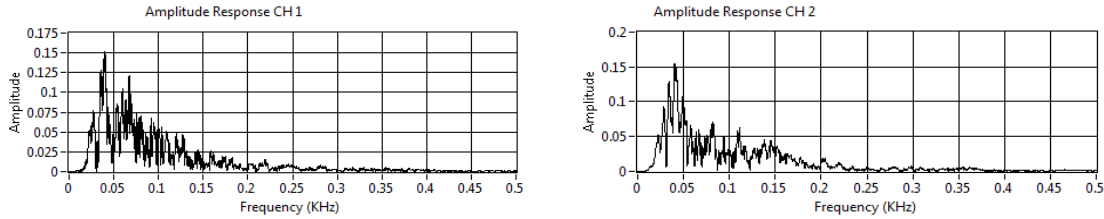(b) Denoised sEMG signal

(c) Amplitude response (0 to 500 Hz)

(d)   Amplitude response (zoomed in 20 to 250 Hz)
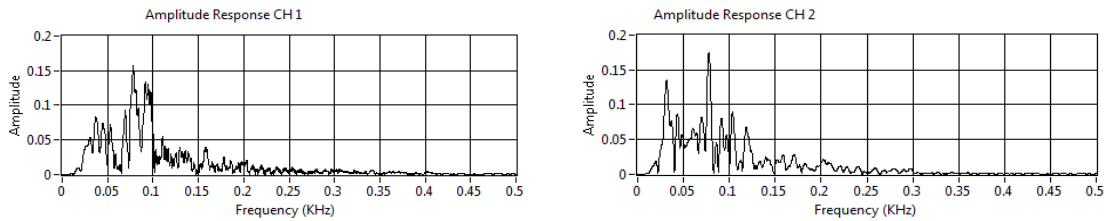Fig. 8:Important plots for alphabet "W" (approximant)

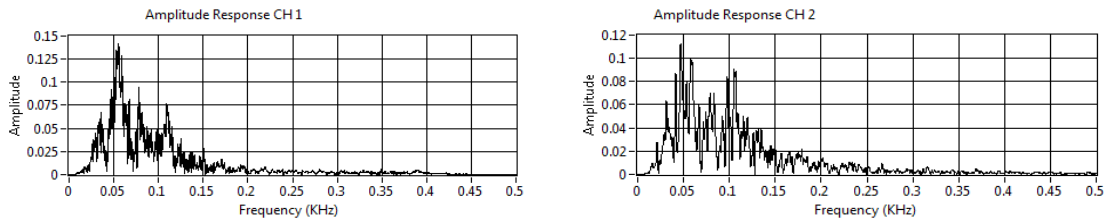(Zygomaticus Major on CH-1 and Levator Anguli Oris on CH-2)

(a) Amplitude response for 'Vowel' alphabet "A"

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor :6.887
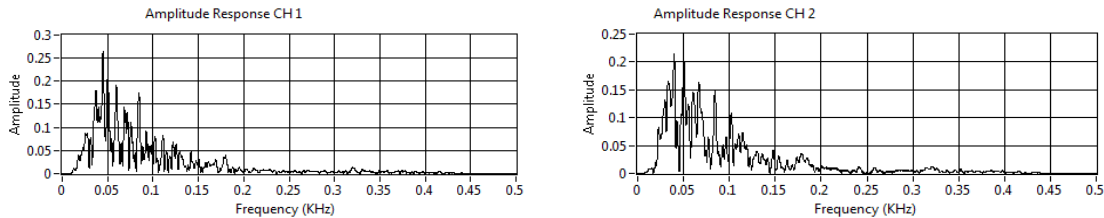*Volume 5 Issue XII December 2017- Available at www.ijraset.com*

(b) Amplitude response for 'Fricative' alphabet "*F*"

(c) Amplitude response for 'Glottal' alphabet "*H*"

(d) Amplitude response for 'Nasal' alphabet "*M*"

(e) Amplitude response for 'Plosive' alphabet "*P*"

Fig. 9:SEMG signal analysis of different sounding alphabets
(Zygomaticus Major on CH-1 and Levator Anguli Oris on CH-2)

Table II: Observed SEMG Frequency Characteristics of Facial Muscles

Alphabet Category	Frequency Characteristics of Muscles			
	Zygomaticus Major		Levator Anguli Oris	
	Dominant Frequency Range (Hz)	Peak Frequency (Hz)	Dominant Frequency Range (Hz)	Peak Frequency (Hz)
Vowel "A"	30 - 150	66	30 - 180	93
Approximant "W"	20 - 185	66	20 - 240	37
Fricative "F"	20 - 160	40	20 - 150	41
Glottal "H"	20 - 160	61	20 - 190	52
Nasal "M"	20 - 150	55	20 - 180	41
Plosive "P"	22 - 180	45	22 - 180	40

VII.   CONCLUSIONS

This paper discusses the design issues and complexities for acquisition of surface EMG signal generated for speech, their amplification and filtering. The system is tested for SEMG data from two channels, via data collection in a PC using NI USB-6009 DAQ card. The noise could be successfully suppressed from the acquired SEMG signals using this setup. The amplitude response so obtained indicates the 10 to 500 Hz frequency band for all categories of alphabets. Various analytical plots show the dominant frequencies lie mostly in 20 to 200 Hz. The peak frequencies range between 40 to 70 Hz for zygomaticus muscles whereas on levator anguli oris muscles it is up to 240 Hz. The plosive (*P*) and fricative (*F*) have lowest peak frequency as compared to glottal (*H*) and nasal (*M*) whereas the peak frequency for vowel (*A*) and approximant (*W*) is highest. The results also demonstrate the usefulness of a battery operated system in eliminating the power line noises.

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