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Acquisition and Wireless Transmission of sEMG signals for Muscle Stress Analysis and Fatigue Detection

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***Abstract* – Surface Electromyography signal (sEMG) acquisition for muscle fatigue detection[1] is very useful for interpreting mechanical muscle output during sports medicine applications and rehabilitation. sEMG is an important measurement for monitoring exercise and fitness. This paper details the procedure to sense sEMG signals (stress level) using pressure sensors (Flex sensors), converting analog signal to digital signal using ADC0808(8-bit) and AT89s52 as microcontroller, encoding(4-bit) the signal, RF transmission(TWS 433) of the signal and decoding it. The signal is received by an RF receiver(RWS 433) and send to the PC via USB port. Amplitude (Stress) vs. Time graph of the signal is then plotted to compare different stress levels using Matlab software. The results obtained are used to study the variation in plotting of signals in accordance to the varying level of forces (stress) the muscles generate to produce movement. This in turn can be used to Identify the "bottle neck" while performing (i.e. which muscle is the first muscle to show signs of fatigue or takes longest to recover). It is also used to select the most effective training/rehabilitation exercise and optimizing its frequency and intensity (i.e. expediting or modifying of rehabilitation progression based on individual responses) and can compare the effects of various ways of taping or bracing (i.e. finding the best model and adjustment for a knee brace).**

***Keywords* - Pressure sensor, real time data acquisition, microcontroller, EMG, EMG signal analysis, muscle fatigue, stress, RF, wavelets.**

I. INTRODUCTION

Electromyography (EMG) is an experimental technique that is significant in the field of the development, recording and analysis of myoelectric signals. Myoelectric signals are formed by variations of physiological nature in the state of muscle fibre membranes.

Needle electromyography (NEMG), is a standard method for studying characteristics of neuromuscular diseases. Fine-wire EMG (FWEMG) is used in the assessing of gait disorders, kinesiologic studies, and research. However, NEMG and FWEMG are both invasive and hence painful, and this is a limitation of their use. Whereas, SEMG is a technique to measure muscle activity non-invasively using surface sensors placed on the skin over the muscles.

While detecting and recording and processing the EMG signal, there are two main issues of concern that influence the signal. The first is the signal to noise ratio. That is, the ratio of the energy of the EMG signal to the energy of the noise signal. In general, noise is defined as electrical signal that is not part of the desired EMG signal. The other is the distortion of the signal, that is the alteration of the relative contribution of any frequency component in the signal.

It is well established that the amplitude of the EMG signal is random in nature and can very closely and reasonably be represented by a Gaussian distribution function. The amplitude of the signal can range from 0 to 10mV (peak-to-peak) or 0 to 1.5 mV (rms) [2][3]. The usable energy of the signal is limited to the 0 to 500 Hz frequency range, with the dominant energy being in the 50-150 Hz range. Usable signals are those with energy above the electrical noise level.

Currently there are three common applications of the EMG signal. They are:

- To determine timings when the excitation to the muscle begins and ends.
- To estimate the force (stress level) produced by the muscle.

- To obtain an index of the rate at which a muscle fatigues through the analysis of the frequency spectrum of the signal.

Inspite of certain experimental difficulties, electrical signals monitored on the skin surface are of enormous clinical, physiological and kinesiological importance.

II. SYSTEM COMPONENTS

The architecture for the proposed sEMG acquisition and wireless transmission system includes components as listed below. The system components are shown in Fig 1.

1. Flex sensor, a passive resistive device is used to detect bending or flexing of muscles. A 3/8" wide by 5" long sensor is used. It is a bi-directional flex sensor that decreases its resistance in proportion to the amount it is bent in either direction.

2. Microcontroller: AT89S52 is used because of its low power, high performance. It is a CMOS 8-bit microcomputer with 8K bytes of Flash programmable and erasable read only memory (PEROM). The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. An 8-bit ADC0808 for converting analog signals to digital.

3. A light-emitting diode (LED) is a semi-conductor light source. LEDs are used as indicator lamps. LEDs emitting low intensity red light are used.

4. RF transmitter and receiver-The RF module, as the name suggests, operates at Radio Frequency. The corresponding frequency range varies between 30 kHz & 300 GHz. In this RF system, the digital data is represented as variations in the amplitude of carrier wave. RF module operating at 433 MHz is used with a transmission rate of 1Kbps-10Kbps.

5. Encoder/Decoder-HT12E is an encoder integrated circuit of 2^{12} series of encoders. It encodes the 12 bit parallel data into serial for transmission through an RF transmitter. These 12 bits are divided into 8 address bits and 4 data bits. The HT12D data decoder decodes the data packet received from the HT12E encoder. If the addresses match, then the HT12D outputs a valid transmission signal on its VT pin and latches on its 4 data output pins, the states of the 4 data bits of the HT12E encoder.

6. LCD at receiver side will display the strength of the muscle in force per unit area. The USB port can be connected to a computer for storage and further processing of the signals.

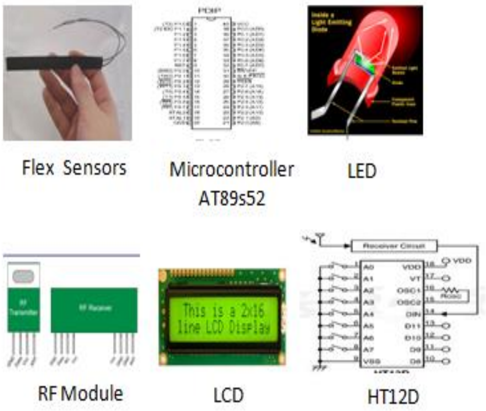

Figure 1. System Components used

III. sEMG SIGNAL ACQUISITION AND TRANSMISSION

The novel idea of this paper is to detect sEMG signal strength and plot stress vs. time graph for muscle fatigue. Flow Diagram for the project is shown in Fig 2.

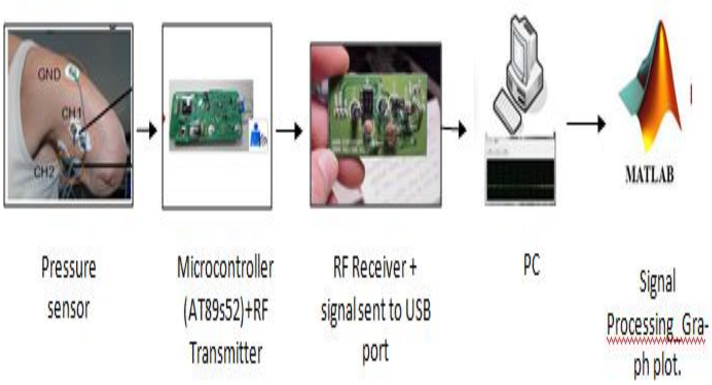

Figure 2. Flow Diagram

Pressure sensor, microcontroller, A/D converter, Encoder/Decoder, RF transmitter/receiver and PC make the hardware of the signal acquisition and transmission system and Matlab is used for signal processing and plotting stress vs. time graph. Block Diagram for various stages of the data transmission and analysis is shown in Fig 3.

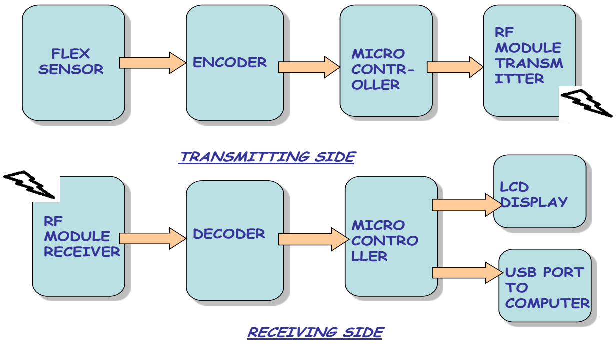

Figure 3. Block Diagram

Flex sensor is used to detect movement in muscle tissues (generally in the arm) due to change in resistance of the sensor when pressure due to force is exerted on the sensor. An un-flexed sensor has a nominal resistance of 10K that decreases when bent. It is used at room temperature. The detected signal is then sent to the microcontroller which is filtered and amplified for noise reduction. Microcontroller AT89s52 has 8K bytes of Flash memory, 256 bytes of RAM, 32 I/O lines, three 16-bit timer/counters, a six-vector two-level interrupt architecture, full-duplex serial port, on-chip oscillator, and clock circuitry. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. There is an LED connected to the microcontroller that blinks, indicating the flow of signal from sensor to the microcontroller. This signal is converted into digital data by inbuilt A/D converter ADC0808(8-bit). Digital data is sent to the microcontroller and further encoded by HT12E. HT12E is an encoder integrated circuit of 2^{12} series of encoders. They are paired with 2^{12} series of decoders for use in remote control system applications. , HT12E converts the parallel inputs into serial output. It encodes the 12 bit parallel data into serial for transmission through an RF transmitter. These 12 bits are divided into 8 address bits and 4 data bits.HT12E has a transmission enable pin which is active low. These bits are then transmitted through RF transmitter (TWS 433) at a frequency of 433 MHz. At the receiver side these 12 bits are received by the RF module and decoded by a decoder (HT12D). It compares its own address configuration with the encoded address received from the HT12E encoder. If the addresses match, then the HT12D outputs a valid transmission signal on its VT pin and latches on its 4 data output pins, the states of the 4 data bits of the HT12E encoder. This decoded data is send to the microcontroller where The LCD interfaced to it twill display the strength of the muscle in force per unit area. All the system components are need +5V and are driven by voltage regulator 7805.The data from the microcontroller through the USB port can be connected to a computer for storage and further processing of the signal. This data is then plotted as stress(amplitude) vs. time graph using Matlab software.

IV. DATA ANALYSIS AND RESULT

The data is transmitted from RF transmitter. The LED blinks when data is flowing from sensor to microcontroller. The LCD on this circuit displays values like ±20%, ±40%, ±60%, ±80% and Normal Activity. Pressure sensor Values in the range 50-60 are considered as normal muscle activity values. Values exceeding ±80% are of high muscle activity. (Note: The experiment is performed on a small scale.)

These values are transmitted to the RF receiver circuit that can be kept at a distance of 10m-12m. The LCD on this circuit board displays the same values as displayed by the LCD on the transmitter circuit board. The LED blinks to indicate flow of data to the receiver from transmitter.

These values are then transmitted to the PC through a USB port. The X-CTU software is used to test the RF transmitter/receiver as the same values on the LCD is displayed in this software window. PL2303 is the USB to serial Driver. Fig. 4 shows the plot for normal muscle activity and Fig. 5 shows the plot when muscle activity is ±60% and is nearing the stress zone.

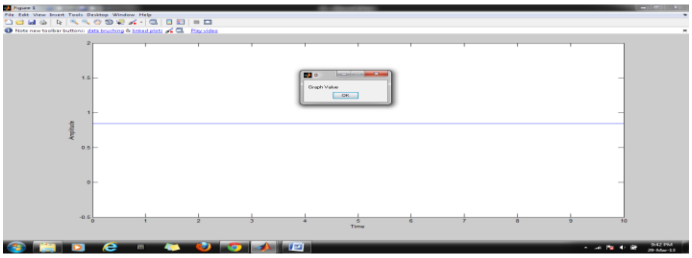

Figure 4. Output for normal muscle activity

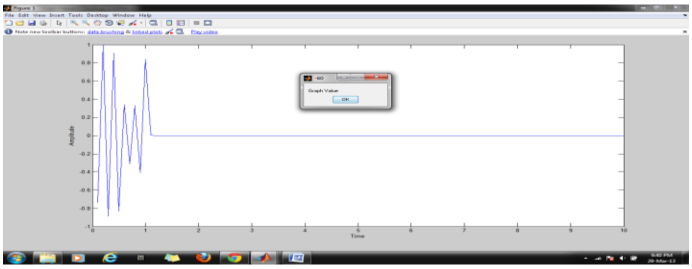

Figure 5. Output for high muscle activity

The speed of values being send to the PC through the cable are very fast, therefore, plotting all the received values simultaneously is not easy. Thus, one value for a set given time interval is taken (This value is selected as the average of some previous values.). It is then plotted in Matlab software. The plot is amplitude(stress) vs time graph and the small dialog box in the window as shown displays the activity value as ±20%, ±40%, ±60%, ±80%.

V. FAILURE ANALYSIS AND PREVENTION

Failure of any one of the components present in the sEMG signal acquisition and wireless transmission [4] can lead to improper analysis of signals and give incorrect results for muscle fatigue detection and affect stress analysis also. For the reason mentioned above, it is essential to provide specifications and crucial failure details about each component. Failure Modes and Effects Analysis (FMEA) [5] includes the various types of analyses that involve prior engineering knowledge and experience which are collectively used to determine the potential modes of failures that a product might encounter during its lifetime. Designing the product with solutions for functions helpful in eliminating or reducing the potential of a failure mode can be easily achieved using a function failure method. The signals are weak and therefore, proper filtering, noise removal and optimum amplification is very crucial. In particular, methods to understand and predict the possible failure modes are considered essential and significant to monitor fault and prevent failure.

VII. CONCLUSION AND FUTURE SCOPE

The system-protoype presented in the paper is characterized by maintaining simplicity and low cost monitoring of muscle fatigue.The project mainly aims at capturing sEMG signals, performing basic operations like noise reduction, amplification, A/D conversion, encoding/decoding and signal plotting using Matlab software. Studies have proposed that sEMG is a useful ancillary in the evaluation of 'muscle twitch', particularly in the assessment of patients with neuromuscular disorders. Gauging the mechanism of low back pain associated with stress and muscle fatigue[6] is difficult although excessive tiredness of muscles due to their de-conditioning, inhibition of muscle activation secondary to pain, and pain-related action have been suggested as possible causes that might be addressed using sEMG. There are numerous applications of sEMG in which this technique is considered the basic. For example, the use of sEMG recordings is routinely used to measure nerve conduction velocities[6] after electrical stimulation of a peripheral nerve. sEMG is used as a technique for studying movement of muscles for recording EMG signals from multiple muscles in other clinical settings, and for monitoring response in experimental circumstances. Use of sEMG signals in robotics is also phenomenal. Development of a new five-fingered under actuated prosthetic hand system[7] based on the EMG signals is being done using neural network with wavelet parameter to discriminate the EMG patterns.

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REFERENCES

[1] Kang -Ming Chang , Shin-Hong Liu , and Xuan-Han Wu, "A Wireless sEMG Recording System and Its Application to Muscle Fatigue Detection", Sensors 2012, 12,489-499.

[2] Manj Benning, Stephen Boyd, Adam Cochrane, Derek Uddenberg, " The Experimental Portable EEG/EMG Amplifier", University of Victoria Faculty of Engineering ELEC 499A Report, August 1, 2003.

[3] Takayuki Sakurai, Masashi Toda, Shigeru Sakurazawa, Junichi Akita, Kazuaki Kondo, Yuichi Nakamura, "Detection of Muscle Fatigue by the Surface Electromyogram and its Application", in 9th IEEE/ACIS International Conference on Computer and Information Science, 43-47.

[4] Dipali Bansal, Munna Khan, Ashok Kumar Salhan, "Wireless Transmission of EMG Signal and Analysis of its Correlation with Simultaneously Acquired Carotid Pulse Wave Using Dual Channel System", in 2010 Second International Conference on eHealth, Telemedicine, and Social Medicine, 125-129

[5] Eubanks, C., Kmenta, S., and Ishii, K. (1997). Advanced failure modes and effects analysis using behaviour modelling. In ASME Design Engineering Technical Conferences, Sacramento, CA.

[6] Núria Massó *, Ferran Rey, Dani Romero, Gabriel Gual, Lluís Costa and Ana Germán," Surface electromyography applications in the sport ", Apunts Med Esport. 2010;45(165):121-130 , accepted February 5,2010.

[7] Jingdong Zhao, Zongwu Xie, Li Jiang, Hegao Cai, Hong Liu, Gerd Hirzinger," A Five-fingered Underactuated Prosthetic Hand Control Scheme*",in EEE Xplore, January 2010.