International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-05, Issue-02, May 2019

Real-time surface EMG Signal processing using virtual instrumentation

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Abstract **Surface electromyogram (sEMG) is widely used to measure muscle activity. The subject on which signal acquisition is been performed has no risk, as it is a non-invasive method for analysis. EMG signal is widely used to control rehabilitation devices like prosthetic arm or leg. In the paper, the sEMG signal acquisition system has been carried out for upper limb prosthetic. This paper shows the processing of these signals generated by the system to control a prosthetic arm with less effort by subject. EMG signal is widely used to control rehabilitation devices like a prosthetic arm. The acquisition of the signal is in real time and then by signal processing, it is converted into a pulse. The pulse output is obtained by contraction of the muscle. The surface electrodes capture the action potential generated by the muscle. The signal voltage is in mV and amplified by a muscle sensor. The Muscle Sensors is connected and used directly with a controller. Envelope signal is obtained from the contraction of muscle via sensor and Arduino Mega. Signals are amplified after that rectified and then integrated by the muscle sensor V3 which is converts analog-to-digital by using Arduino Mega. In LABVIEW signal converts the Envelope signal into a pulse signal which can be used in several applications.**

Keywords — **Real-time *s*EMG, Signal processing, Arduino, LABVIEW, Pulse generation, Muscle sensor.**

I. INTRODUCTION

The sEMG signal is used for many applications in which doctor get help to detect and analyze the problem in muscle. Signals could prove to be a diagnostic tool for estimating muscle fatigue or for evaluating patients with neuromuscular diseases, low backache, and disorders of motor control [1]. sEMG acquisition quality is influenced by different parameters including inter-electrode distance (IED), EMG electrodes position and electrodes configurations [2-3]. With the development of computer science and electronic measurement technology, virtual instruments technique based on the platform of microcomputer, which contains data processing, analyzing, illustrating and storing, has developed rapidly. It overcomes the shortcomings of simplex function and complex operation in traditional instruments and thus has been applied in many fields [4].

EMG signals have been used in the medical engineering field in relation to the tracking of trajectories. A successful application that has been in the market for more than three decades is the EMG-driven prosthetic arm and hand. Recently, EMG-based control systems have taken a new direction. Several studies have suggested the use of EMG signals as a method of interaction with machines. However, most of the EMG-based movement recognition systems are restricted to planar movements. The rest involve single joint movements or hand pose interpretation. Moreover, all of the EMG based arm movement analysis systems have used at least six muscles and such a number of monitored muscles might restrict the user's movements [5-6].

In this paper, the EMG envelope signal is acquired from a muscle sensor in LABVIEW. The muscle sensor can be connected to microcontroller directly. The sensor does not give a RAW output but rather gives an output which is preprocessed. The gain can be adjusted and the analog signal is fed to the microcontroller for analog to digital conversion (ADC). The maker hub is used for interfacing between the controller board and LABVIEW. The Real-time signal is acquired and converted into pulse which can be fed to rehabilitation prototype arm. The system works on real-time signal processing and is entirely low-cost system.

II. METHODOLOGY

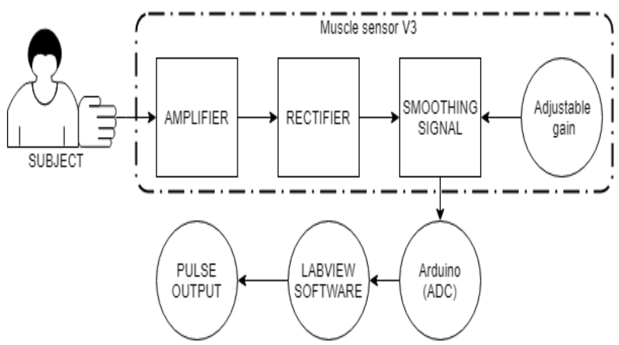

Figure1. Block Diagram of system

 DOI : 10.35291/2454-9150.2019.0127

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The electrodes are placed on the muscle and connected to muscle sensor circuit using the leads. Muscle sensor has the own signal processing circuit like amplification, rectification, and smoothing of the signal. Also, the gain of the circuit has adjustable gain. In order to get the signal for analysis and storing we need to convert it to a digital form.

The Arduino plays a role to convert the signal from analog to digital and then the signal can be transferred to the computer using USB connection. LABVIEW is interfaced with the Arduino using maker hub library and data is saved for future use. The entire software logic was developed to convert the analog signal to a PWM signal for servo motor.

A. HARDWARE:

1.Muscle sensor V3:

The muscle sensor V3 measures a muscle's activity by monitoring the electric potential generated by muscle cells. This is referred to as electromyography (EMG).

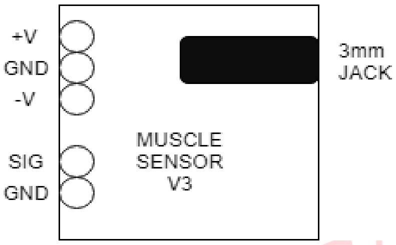

Figure2. Muscle sensor pin diagram

The sensor amplifies and processes the complex electrical activity of a muscle and converts it into a simple analog signal that can easily be read by any microcontroller with an analog-to-digital converter (ADC), such as Arduino. The muscle sensor has an adjustable gain on it and a 3mm Audio jack is for the input from the three surface electrodes.

2.Positive and Negative 9v power supply:

Two power supplies are required. The sensor needs a positive and negative ref. voltage. The sensor has a maximum operating voltage of plus or minus 18v. To avoid an electric shock the minimum 9v supply is suitable. A 9v constant supply is provided to the sensor for stable output.

3. Arduino Board (Uno or Mega):

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started [8].

4. Surface electrodes:

Surface electrode converts ionic current to electrical current. Disposable electrodes or small device that is attached to the skin to measure the action potential generated in muscle. Surface electrodes may be used to look for problems with muscles and nerves.

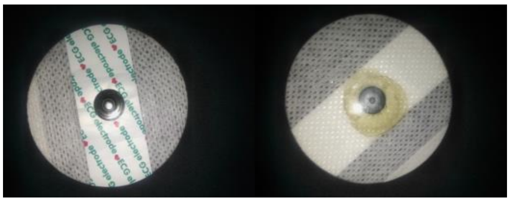

Figure3. Surface Electrode.

5. Connecting Wires:

There are 3 connectors red, green and yellow to drive signals from electrodes to muscle sensor. The first electrode is connected to the RED Cable's snap connector and place in the middle of the muscle. The second electrode is connected to the GREEN Cable's snap connector and place in one end of the muscle. The third Electrode is connected to YELLOW cable's snap which is placed on a bony or non-muscular part of the body.

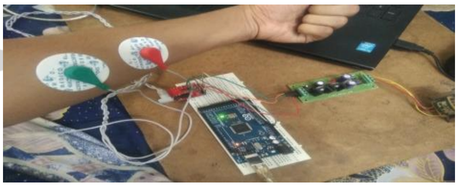

Figure4. Electrode Placement

B. SOFTWARE

PROCESSING TECHNIQUE:

1. Data acquisition:

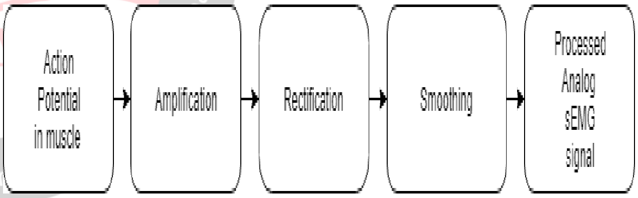

Figure5. Blocks of Data Acquisition

Figure6. Data Acquisition from Subject

EMG is nothing but measuring an electrical signal related to the activation of the muscle. This may be forced or unforced muscle contraction. The EMG activity of forced muscle contractions is related to tension. The muscle contraction of the functional unit is a motor unit, which is

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comprised of a single alpha motor neuron and all the fibers it enervates. This muscle fiber contracts when the action potentials supply reaches a depolarization threshold. The electromagnetic field is generated by the depolarization and the potential is measured as a voltage.

Voltage is in µV so it needs amplification. The EMG signal quality depends on the electrodes and partially dependent on the properties of the amplifiers. The amplitude of the EMG signal is weak and typically in the range of tens to thousands of µV. So, it is necessary that the gain of the amplifiers used in EMG applications is in the range from 1000 to 10000. Adjustable gain is used to set it according to requirement. For the signal normalization, we need to move the entire negative signal to the positive. The gain (G) is adjustable through the equation[7]:

$G=1+(50k\Omega/RG)$ where RG is an external resistor.

The positive signals will create the peaks showing the area of contraction of muscle or action potential generated. For rectification, the full-wave rectification is carried out. The rectification method used here is taking the absolute value of the signal. Next step is to Smooth signal or envelope of the signal is applied to the rectified signal which gives the processed analog output.

Acquisition of data is a very critical part of this system. To acquire data from the muscle has to take several precautions while placing electrodes and connecting the wires to the system. Electrode captures the signal activity in a muscle when contracted, so electrode placement is such that more activity muscle part of the hand is selected. The hardware error can be generated if no stabilize power supply is provided or gain is not set accordingly.

2. Signal processing:

EMG signal pattern is unique for each type of muscle movement. Different algorithms have been proposed to classify the EMG signals. The most common algorithms employ the comparison of the signal amplitude with a predefined threshold value. But there are many problems associated with this type of signal classification and can be easily overcome by involving the width and duration of the signal components in the decision-making process.

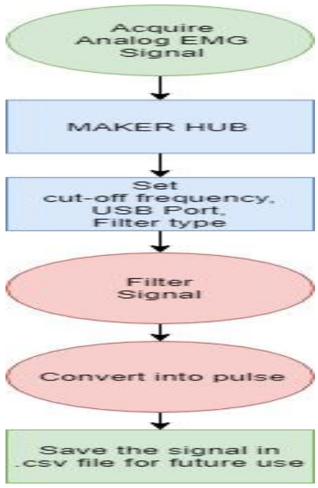

Figure7. Signal Processing Flow-model

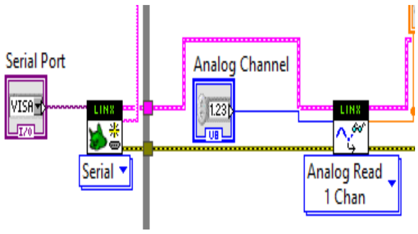

Figure8. MAKER HUB Palettes to Select Port and Channel

Signal processing is carried out in LABVIEW and the signal acquired is an analog signal. The signal is input to the interfaced Arduino via. MAKER HUB which converts the signal to digital for digital processing. Some values have to be set before plotting the signal like low and high cut-off frequency, sampling frequency, type of filter and its filter order. The serial port is selected and the channel is defined to capture the analog signal for processing. The envelope signal is plotted in real-time on the graph in the front panel. To analyze the signal the subject was asked to contract the muscle, on every contraction envelope signal was acquired and on relaxing no muscle response was seen on the graph.

As the processing of the signal is already done by the sensor, conversion of the signal may affect the signal and added some noise. To remove the noise the signal is needed to be filtered. The Butterworth low pass filter is used as it removes the unwanted interferences in the signal. The servo motor needs PWM signal to operate so filtered output signal is converted into pulse which can be fed to drive servo motor.

3. Data Storing:

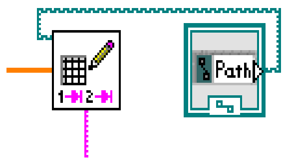

Figure9. Delimited spreadsheet palette

For every contraction of the muscle, the pulse is generated in real time which can be fed to several applications. The real-time generated signals are saved in

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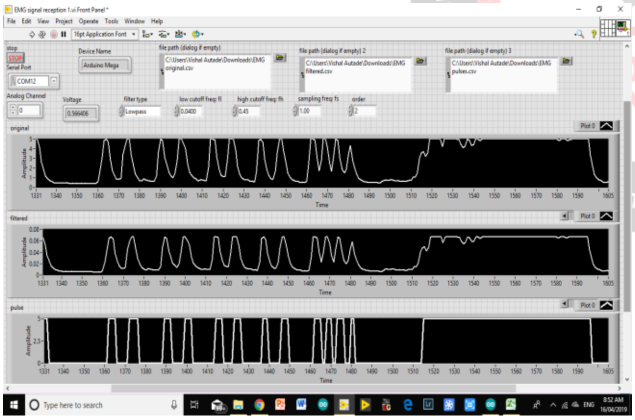
file format using the write delimited spreadsheet palette. The saved file format is in a .csv file. The signal can be stored to analyze the different subjects muscle response which will be helpful to analyze the amount of action potential generated by the muscle of amputee.

III. RESULTS

1) The subject was asked to contract muscle by closing fist just for 1sec and release in result1 to acquire single pulse output. Then at the end of graph subject was asked to close fist loose to observe contraction response at the output.

a)

2) In second result the subject was asked to close fist twice so we get two consecutive pulses and at the end of a graph subject was asked to close fist tightly possible to observe the response.



b)

Figure10. a) Result1 b) Result2

Real-time EMG signal converted into PULSE output.

IV. CONCLUSION

For the medical and clinical application, several characteristics can be obtained by acquiring accurate signals. The Design of sEMG real-time envelope signal is acquired and converted into a pulse signal. The successful interface between hardware and LABVIEW (i.e. software) was established and the quality signal was acquired with high SNR. For every contraction of the muscle Burst signal is acquired and converted into a pulse. The signal is saved in file format for analysis or future use. The cost of the system is low and reliability is high and can easily be updated with future advancement in system.

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