

Design of Wearable, Low Power, Single Supply Surface EMG Extractor Unit for Wireless Monitoring

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Abstract. Aim of this paper is to design a low power, single supply wearable EMG extractor unit for wireless EMG monitoring. Preamplifier section is designed with instrumentation operational amplifier AD623 located at the site of extraction through Biopotential electrode. Acquisition and processing of multichannel EMG signal is done by ATMEGA 8 processor. Data is transmitted to computer with c#.net platform for signal processing and visualization through RF module. Surface EMG amplitude and torque about elbow joint under yielding isometric contraction measured is used as a parameter to study nature of bicep muscle which also verifies system design. Design features suites its application in gait analysis, orthotic and prosthetic design, ergonomic and rehabilitation processes.

Keywords: Surface EMG, Biopotential electrode, Yielding isometric contraction.

1. Introduction

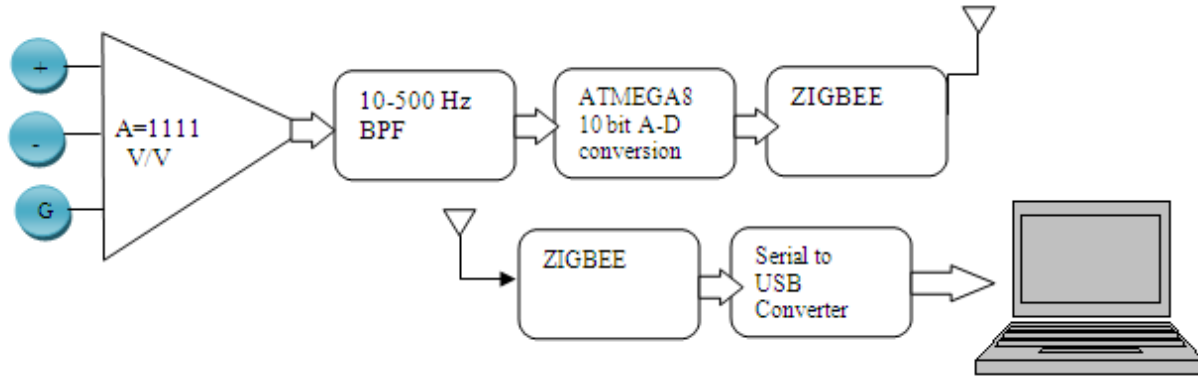
Small electrical currents are generated by muscle fibers prior to the production of muscle force. These currents are generated by the exchange of ions across muscle fiber membranes, a part of the signaling process for the muscle fibers to contract. The signal is called the electromyogram (EMG) can be measured by applying conductive elements or electrodes to the skin surface, or invasively within the muscle. The source of the SEMG signal is the motor unit action potential (MUAP). Action potentials are given off by each of the motor units activated during a given contraction. In any given recruitment pattern, populations of motor units are activated in an asynchronous pattern. This asynchronous pattern of activation provides the possibility of smooth movement. It is the sum of the activity that constitutes the volume conducted signal, which is picked up at the electrodes and amplified by the SEMG instrumentation amplifier. Surface electromyogram (sEMG), which represents activation states of muscles, has been widely used in muscle strength measurement, rehabilitation, torque relation and human-robot interaction because of non-invasiveness and easiness. Difficulties lie in signal extraction due to very small voltage of about few micro volts, very high input impedance of human skin, signal distortion by noise, motion artifacts and real time processing. In designs available subjects are physically restricted with the present EMG device because of connecting wires between electrode and the transmitter. Moreover, this device can be affected by noise resulting from the movement of the wire. Bulky size and high power consumption makes them quite unfit for use in wearable system for prosthetic use, gait analysis etc.

Proposed design is quite unique and is specially suited for wearable prosthetic applications due to low power consumption, wireless design and display with biofeedback. EMG signal is acquired from 3 subjects using Biopotential electrode and EMG preamplifier unit. Signal is filtered and processed to extract root mean square value in visual studio platform. Torque measurement is done with uniformly varying load and Torque- EMG relation is plotted. To combine different factors effecting torque-EMG relation, a muscle strength index is developed. Torque EMG relation is displayed with a visual chart which enhances user's interaction by providing a biofeedback.

2. System design

The developed EMG system consists of disposable Biopotential electrode as sensor, a dual channel preamplifier module which measure and amplifies the EMG signal, ATMEGA8 processor for data acquisition, RF module for wireless transmission and a computer with visual studio platform for signal filtering and display.

2.1. System Block Diagram



2.2. Biopotential Electrodes

EMG is muscle action potential signal which are bio signal of the order of few microvolt. To extract this signal we have used Ag/AgCl Biopotential disposable electrodes. The AgCl layer allows current from the muscle to pass more freely across the junction between the electrolyte and the electrode. This introduces less electrical noise into the measurement. Proper skin preparation and placement of electrodes are necessary. For single channel acquisition three electrodes are needed, two serves as active electrode and one ground electrode. The inter electrode distance is kept 20mm according to SENIAM recommendation for surface EMG measurement.

2.3. Preamplifier Circuit

EMG signal varies from a 6 microvolt to 200 microvolt range and frequency band is extended from 10Hz to 500Hz. It is also important to use very high input impedance amplifier because of high impedance between skin and the electrodes. Due to microvolt level input signal and very high input impedance, the choice of a low noise amplifier is also very important consideration. As the system would be wearable, so low power, small size and light weight is also important issue. We have initially used AD620 which processes stable gain range up to 1000, 10G ohm input impedance and very low noise. It performed well, but requirement of dual polarity supply (+5v, -5V) imposed difficulty of running the system with batteries. Later we finalized the design with AD623, which also gives same gain range, 2Gohm input impedance, and low noise operation. Main advantage of using this IC is its single supply and low voltage operation. It works well with only +3V. Preamplifier design is divided in 2 stages. Use of 11 and 101 in the respective stages makes a total gain of 1111. AC coupling of two IN-amps especially in single supply operation is a bit challenging due to very high input impedance of in-amps and after the DC blocking capacitor, the voltage swing is well below ground. The first problem is solved by providing a ground return from the input of the second stage by a 10K resistor. The second problem is solved by using very low gain of only 11 and thus limiting the max voltage swing after the capacitor to 150mV, which is inside the permissible input voltage range of AD623. Differential signal from two active electrodes is amplified according to equation- $V_0 = (1 + 100K\Omega/R_G) * V_C$. There are 2 such preamplifier sections for dual channel EMG extraction.

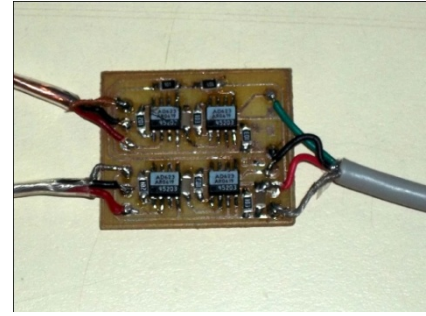
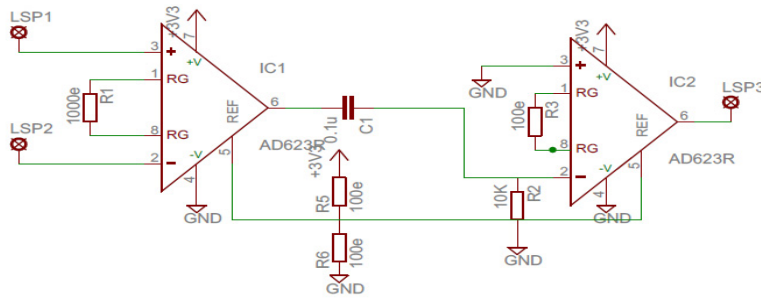
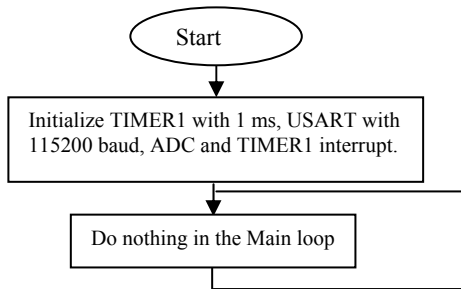


Fig. 1: Schematic of AD623 based preamplifier and right side picture shows the practical circuit.

2.4. Processor unit

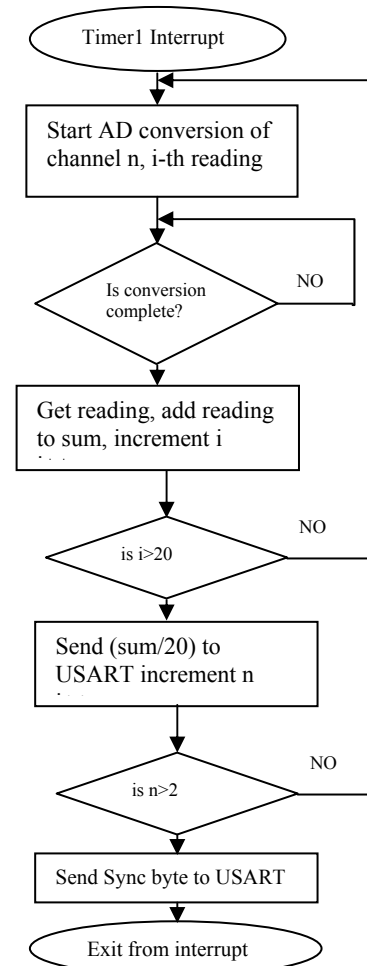
Amplified EMG signal needs to be digitized for further processing. ATMEGA8 microcontroller is used for data acquisition. 10 bit, 6 channel A/D converter used with a sampling speed of 1 kHz. The Sampled data is sent to the USART with a baud rate of 115200 bps. Here is the flow chart of the embedded C program written for the implementation of the system. We have used the built in calibrated internal RC oscillator to minimize the noise generated by the crystal. Also use of the noise reduction mode of ATmega8 minimized digital switching noise in the circuit.



Resolution: It is important to know the actual resolution of the system in order to find out the actual input voltage and also the dynamic range. This is dependent on ADC resolution, ADC settings, and the preamplifier gain.

In our case the ADC resolution is 10 bit, reference voltage is +5V and preamplifier gain is 1111. The resolution can be found out by the following equation

$$\begin{aligned}
 \text{Resolution} &= (\text{Reference voltage}) / (\text{ADC resolution} * \text{Gain}) \\
 &= 5 / (1024 * 1111) \text{ Volt} \\
 &= 4.394 \text{ Micro Volt}
 \end{aligned}$$



Wireless RF module: XBEE digimesh 2.4 OEM RF module is used for wireless transmission. XBEE module operating range is within medically prescribed standard. It provides reliable and high speed data transmission. It has been used in the system for indoor application up to 30metre range. XBEE module draws low current of about 50mAmp and runs in 3.3volt supply which further aids the system in low power design.

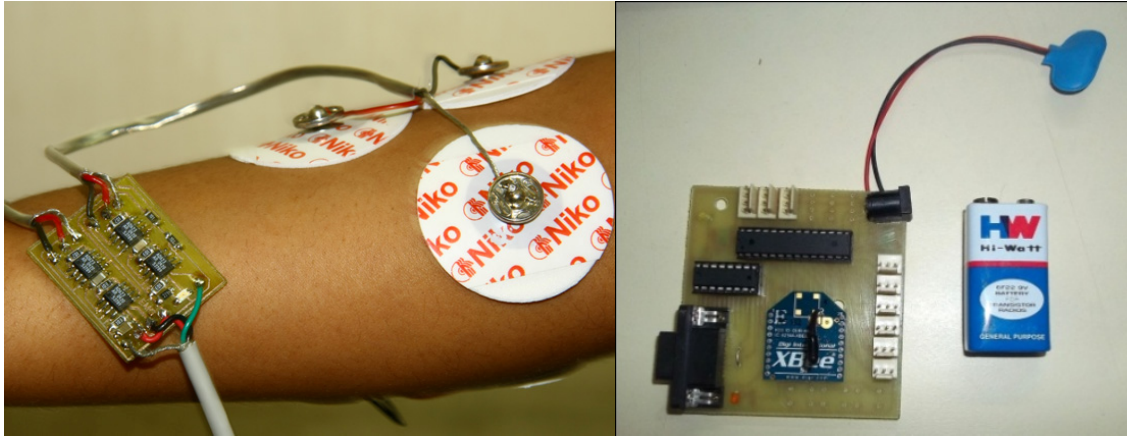


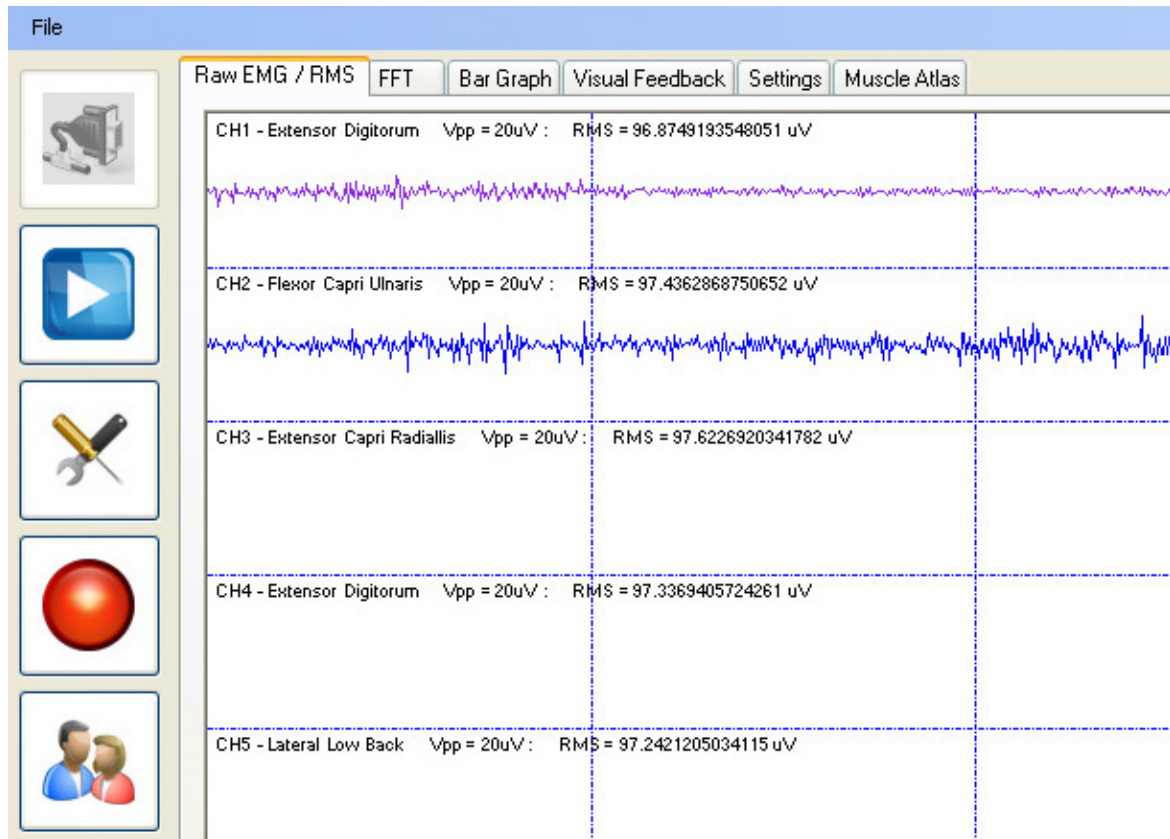
Fig. 2: showing Biopotential electrode placed on Forearm Flexor Muscle, and ATmega8 with ZIGBEE

2.5. Software Section

Raw EMG signal is treated in software section to extract useful features. EMG Signal is divided into 50ms window length. Moving window averaging is done. From raw EMG signal we extract root mean square value whose amplitude can be related with force or torque applied. 20 consecutive RMS values are averaged and displayed in a 1 sec display window, averaging causes low pass filtering. Digital band pass filter is designed for 10 to 500Hz frequency pass band. A bar chart representation has been designed which increases or decreases its value according to force or torque applied thus giving a visual feedback to user. Single channel unwhitened amplitude processor was formed as simple RMS processor. There is a acquire button, which saves the raw EMG data in file which can be used offline for further processing.

$$\text{EMG amplitude estimate } S_i(t) = \sqrt{\left(\frac{1}{N}\right) \left(\sum_{i=t-N+1}^t (m^2(i)) \right)}$$

where, N= smoothing window length, m= waveform at sample time t.



3. Experimental set up and result analysis

EMG extraction system is used to extract EMG signal against torque applied at elbow joint to study bicep muscle behavior and torque-emg response against yielding isometric contraction. EMG signal is acquired from 3 subjects using bio potential electrode and EMG preamplifier unit. Signal is filtered and processed to extract root mean square value in visual studio platform. Torque measurement is done with uniformly varying load and torque- EMG relation is plotted. Torque is measured with respect to elbow joint. For yielding isometric contraction, elbow joint is kept at 90 degree with respect to upper arm where upper arm is in horizontal position. Load is applied at the end of wrist and distance is measured from elbow joint. Load is applied with help of a spring balance and it is varied from 500 gm to 5 kg in slow succession providing rest in between. Force due to load multiplied by the fixed distance gives torque. EMG signals are acquired simultaneously and reading in software shows variation in EMG data with change in torque.

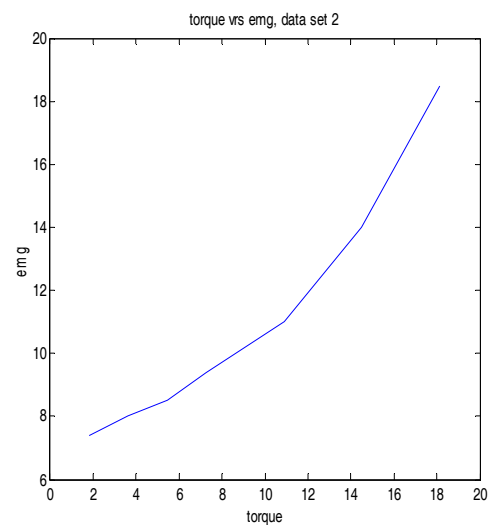


AGE=25 yrs, HEIGHT=6'1", WEIGHT= 90KG, SEX M

MUSCLE WIDTH =36 cm, MUSCLE LENGTH =20.5 cm,

LOAD APPLICATION LENGTH = 37 cm, OFFSET EMG =5.5

Weight(kg)	Torque(N m)	EMG(rms value)
0.5	1.818	7.4
1.0	3.626	8.0
1.5	5.439	8.5
2.0	7.252	9.4
3.0	10.878	11.0
4.0	14.504	14.0
5.0	18.13	18.5



4. Conclusion

EMG extractor unit designed gave reliable output readings during EMG torque experiment. Gain over the time was constant without much drift. Torque EMG relation of bicep muscle showed nonlinear nature which would be better represented if factors like muscle width, activation volume, conduction area and other physiological factors are also considered.

The proposed design fits its purpose of being a low cost, low power single supply extractor unit. Overall system runs on 3.3v which extends battery life for long term use, system can be run using only three pencil cells. Compact size and extremely low weight about 100gm makes it an ideal wearable device. Incorporation of the wireless XBEE module which operates in 2.4GHz ISM band ensures all medical protocols and also provides reliable and high speed method of data transmission. It further makes the system compact offering complete freedom of mobility during experiments.

5. Acknowledgement

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6. References

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