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Instrumentation of a Portable EMG Sensor in a Single PCB for Human Motion Pattern Detection

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Abstract—**The objective of this work is to make a Surface Electromyography (EMG) signal detection sensor to test and analyze human motion pattern. EMG signal has a very small amplitude level and a frequency range of 20 Hz to 200 Hz. In order to realize the sensor, a circuit and its single layer PCB has been designed to amplify and filter the differential potential between Ag/AgCl electrodes at different points. After that the signal has been stored in computer using NI ELVIS II (DAQ) and LABVIEW at a sampling rate of 1000Hz. Then the signal has been used to calculate the stride length of a particular foot by a single threshold comparison method. The ultimate result shows that the calculated and actual stride length matches in 89% of the cases.**

Keywords—Printed Circuit Board (PCB); Signal conditioning Circuit; Instrumentation Amplifier; Band pass filter.

I. INTRODUCTION

Biomedical signal analysis is one of the important ways to monitor parameters of the health conditions of human body. Some important biomedical signals include Electrocardiography (ECG), Electromyography (EMG), Electrooculography (EOG) etc. These signals are generated due to the bioelectric signals, that generates across the cell membrane. EMG signal generates due to the bioelectric potential, that generates in the mussel tissues. In resting state, the concentration of Sodium ions outside the cell is higher than inside, which causes a slightly negative potential across the membrane. During some excited state Sodium ions rush into the cells and Potassium ions try to leave the cell. Sodium ions enter the cell rapidly and Potassium ions cannot exit the cells at the same rate, causing a slightly positive charge across the membrane [1]. Thus, a potential difference can be seen during different excited states of muscle tissues.

These signals are of immense importance in the medical field. Different disease can be detected as well as proper analysis of the signal can yield the future health condition of a healthy individual. EMG signal can be utilised to detect diseases like Huntington's disease, Myopathies And Muscular dystrophies etc. EMG has its use in sports world also. It is used to analyze the muscle strength and weakness of a sports person's muscle. It can also be used to suggest running style to a sports person to produce more productive result during different sports. Modern research also showed that EMG can be used to analyze gait, which can be used as a biometric tool. Gait can also be used to diagnose different disease like Parkinson's diseases, Spondylosis [2]-[4] etc.

These above mentioned applications require a noise free EMG signal. The bio-potential generated at any point in human body is due to different excitations, that is causing different voltage and frequency. Due to this reason, if we measure potential at a point it generates an inconclusive signal. This is also enhanced by other external effects like power line interface, body movements etc. Hence a filter is needed to extract useful information from the noise like signal. Moreover the signals are usually of very small amplitude. Therefore it is also required to amplify the signal with proper gain. This paper describes a EMG signal conditioning circuit with its Printed Circuit Board (PCB) to make a portable device to analyze human Gait cycle. Stress has been given to make the output noise free and less bulky. At last the signals generated by the device have been used to calculate the stride length of the signal.

Over the years a lot of work have been published, that contains instrumentation of EMG sensor [5,6]. Other important issues like, EMG sampling has been discussed in [7]. [8] describes different types of noise in EMG signal along with its electrical properties. Different types of electrodes and its placement strategy has also been discussed in[8, 9]. In [10-12] EMG based different online monitoring has been showed. Taking all these in forward a PCB has been designed to calculate the stride length. In order to calculate the stride length different algorithms have been proposed in [13, 14] to detect the onset and offset of stance and swing phase of a gait cycle. Here, a simple threshold based algorithm has been used, to calculate the onset and offset of different gait phases.

The article is structured as follows: section II gives the methods introduced in the work; section III presents an overall result of this technique and section IV concludes the paper with a discussion of the result.

II. METHODS

The block diagram of the circuit has been shown in Figure 1. The amplifier block amplifies the signal and the filter block band passes the signal to get an EMG signal which is sensitive towards muscle contractions and expansions. After the filter

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block, the signal has been sent to data acquisition block, in which the signals have been stored in computer using NIELVIS-II DAC. There after the signal has been analyzed to detect the periodicity to calculate the stride length of human gait cycle.

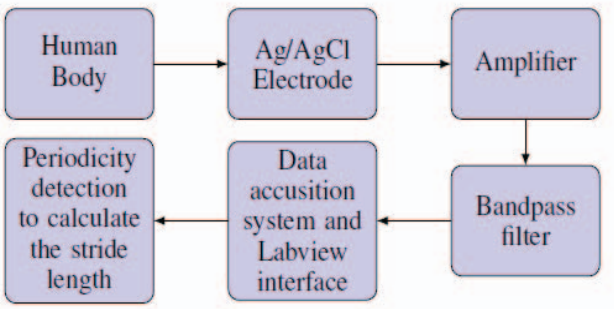

Fig.1. Basic block diagram of the work

All the blocks introduced in Figure 1 along with PCB designing, fabrication and signal processing have been discussed in details in the following subsections.

A. *Ag/AgCl electrodes*

Ag/AgCl electrodes have been used to detect the bio potential, that is generated across two different points due to muscle contraction. Electrolyte gel has been used as an interface between the surface electrodes and muscle tissues. It contains chloride ions. Hence it enhances the charge flow between the tissues and electrodes. The discharge of Cations happens due to oxidation of Silver atoms and due to this effect electrons carry charge through the lead wire. In the other electrode the chloride ions are reduced with the help of electrons travelling towards it [15,16]. Due to this redox reaction a voltage difference can be seen between the two electrodes. Ag/AgCl electrodes has been chosen over other standard electrodes due to its low half cell potential(around 220mV), low and less drift of diffusion potential, temperature insensitivity, ease of use etc. In this work two electrodes have been placed near Soleous muscle and Vastus medialis.

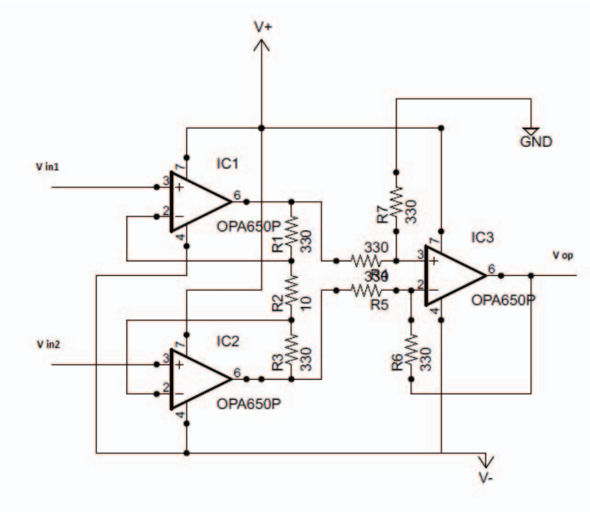

Fig.2. Circuit of Instrumentation Amplifier

B. *Instrumentation Amplifier*

The signal amplitude detected by the Ag/AgCl electrode is very low (typically in the range of m-volts). Hence in order to do any operation, it is needed to amplify the signal to desired amount. In this work an Instrumentation amplifier (Figure 2) of gain 66 has been designed [17]. The gain has been chosen 66, because the depolarization of a cell produces a potential of -90 mV. The absolute value of it is highest in comparison with the absolute value of voltage during re-polarization [1] phase of a cell. Hence a gain 66 will produce a maximum drift of potential -5.94 V, which will neither clip nor be small in amplitude to filter. Instrumentation amplifier [17] has been used because of its low noise, low DC offset, low drift, high input impedances, high open-loop gain, high common-mode rejection ratio and great accuracy and stability.

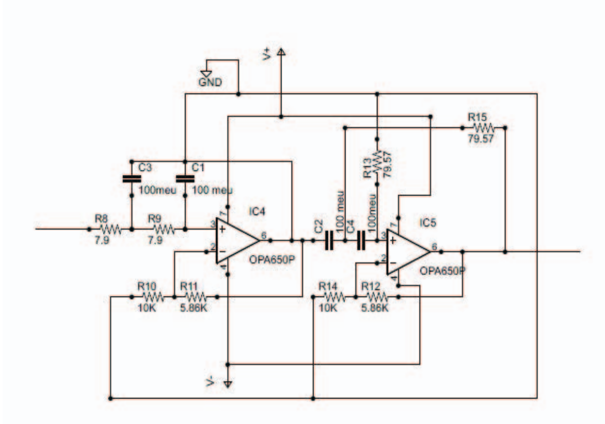

Fig. 3. Circuit of Band pass filter

C. *Instrumentation Amplifier*

Filtering is the next step after amplification. The bio-potential detected by Ag/AgCl electrode contains interference [18] signal due to other sources. Hence a filtration is needed to extract the EMG signal only. EMG signal exists between frequency ranges of 20 Hz to 200 Hz [1]. Therefore a second order Butterworth [18] active band-pass filter (Figure 3) has been used to extract the desired signal. In order to realize the band-pass filter, a low pass (cut-off frequency 200 Hz) and a high pass filter (cut-off frequency 20 Hz) has been designed. The ultimate band-pass filter has been made by cascading the two aforementioned filters.

D. *Power Supply*

Our ultimate goal has been to make a portable EMG sensor. Hence a DC stable power supply has been needed, which is stable in terms of output and contains less space. In order to accomplish the task, a centre step down transformer has been used, which converts 220 V AC to 12 V AC. Thereafter, bridge rectifier along with a capacitor filter has been installed to convert the AC voltage to DC voltage. After that, IC 7805 and IC 7905 has been used to generate +5V and -5V respectively. The circuit has been shown in Figure 4.

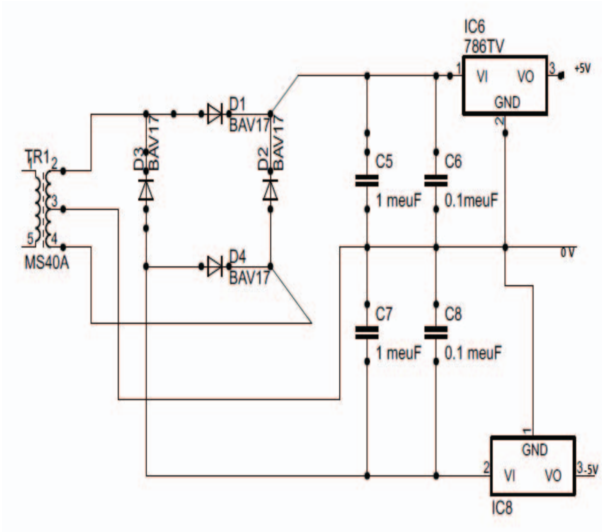

Fig. 4. Circuit of DC Power supply

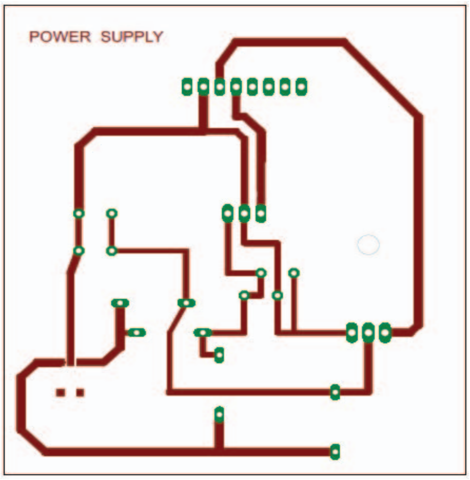

Fig. 5. PCB layout of DC power supply

E. PCB design and fabrication

The next task after designing is to test the circuit. After successful testing, the circuit has been finalized to design the PCB. A single layer PCB has been made. During designing the PCB, different layouts have been designed for the three different aforementioned circuits. The PCB layouts for the power supply, band-pass filter and instrumentation amplifier have been shown in Figure 5, Figure 6 and Figure 7 respectively. The reason for making different layout for different circuits is that, it will be easier to maintain and detect faults in the long run. The layout figures don't indicate the proper size of the PCB. The actual dimension of the layouts of the power supply, band-pass filter and instrumentation amplifier are (7 cm X 7.5 cm), (7 cm X 9.5 cm) and (7.5 cm X 7.5 cm) respectively. Three different PCB layouts have been fabricated and the internal connections have been made via the ports on individual PCB.

The fabrication of the PCB has been done by the following steps. At first the PCB layout has been printed on a paper. The printed side of the paper has been attached tightly on the Copper cladding surface. Then the paper along with the cladding has been heated uniformly to transfer the pattern to the cladding. After transferring the pattern to the cladding, it has been kept in a cool place to reduce the temperature back to the normal room temperature. Then the cladding has been placed in a solution of H_2O_2 and diluted HCl to etch the undesired portions (not wired) of Copper. After this step, the PCB has been washed with clean water. Then it can be seen that, the wired portions of the layout design has been transferred to the cladding. After that, the next steps are to drill, placing the components in proper place and soldering to make the board workable.

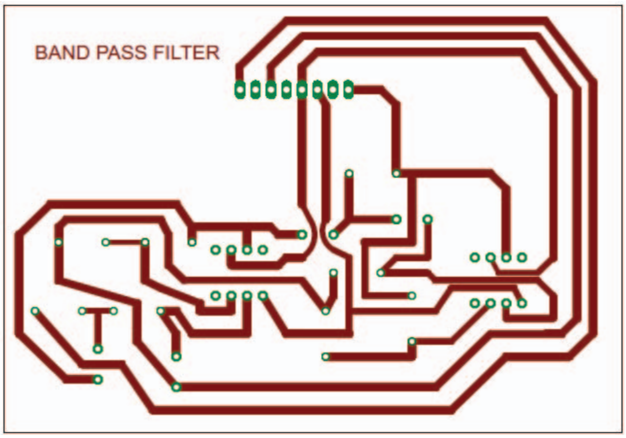

Fig. 6. PCB layout of Band Pass filter

F. Interfacing with Computer

After making the PCB, it has been tested again by putting the electrodes at proper places. The next work has been to make a data interface between the PCB and computer for data storage. This has been done by using NI ELVIS II-DAC and lab view software. Different data sets, during Normal human gait have been stored by using the aforementioned strategy at a rate of 1000 Hz.

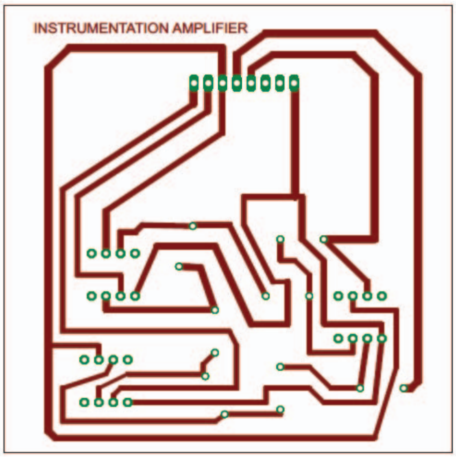

Fig. 7. PCB layout of Instrumentation amplifier

G. Signal Processing

In order to further process the gait data of different persons, signals have been collected by putting the electrodes near Soleous muscle and Vastus medialis. In a normal walk of an individual, it is tough to control the speed. Different value and direction of speed produces different stride length. In order to fix the human walking speed, the signal collection has been conducted by putting several healthy individual (7 person) on a fixed speed treadmill. In all these cases the total time limit of the experiment is different. This is due to the fact, that every human attains steady state gait after different time. A typical signal of normal human Gait cycle on a treadmill has been shown in Figure 8. The next task has been to calculate the stride length for a particular foot. To calculate the stride length of the collected signals, at first the signal has been divided according to its time period. The time period has been calculated by auto-correlation [19]. The equation of auto-correlation has been shown in equation (1). The result of autocorrelation has been shown in Figure 9. It can be seen from the Figure 9 that, autocorrelation produces peaks after each equally spaced time. This equally spaced time is called time-period of the signal.

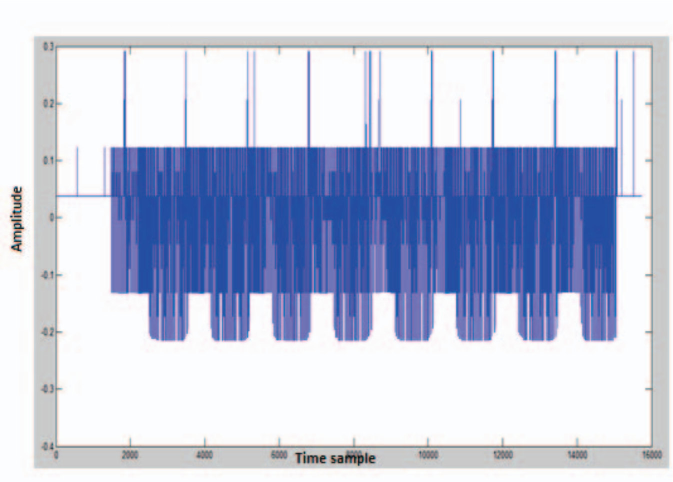

Fig. 8. Human Gait cycle EMG signal collected by the PCB

After dividing the signal according to its time-period, the onset and offset of stance phase (the phase when the foot is touching the ground) and swing phase (the phase when the foot is on air) in each period of the stored signal has been detected by comparing with a threshold [20]. Then accounting the time in all the cases, the time difference between two consecutive stance phase has been calculated - which is known as stride length for a particular foot.

$$R(\tau) = \int_{t_1}^{t_2} f(t)f(t+\tau)dt \tag{1}$$

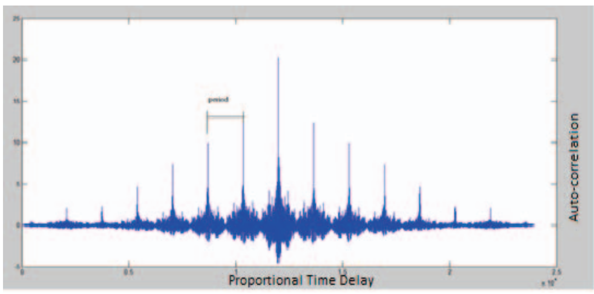

Fig. 9. Auto-correlation of the collected EMG signal

III. RESULTS

The output of the PCB has been shown Figure 8 during normal human motion. The output clearly indicates two voltage level indicating stance and swing phase. The signal processed stride length time has been compared with a video recording of the event. The comparison shows that, around 89% of the gait cycle shows nearly equal stride length in both cases and the rest of the cases show a maximum absolute error of 1/4th of the stride length time of particular foot.

IV. CONCLUSION

In conclusion it can be said that, the PCB can be reliably used as EMG sensor to analyze human motion pattern .The threshold based algorithm also detects the onset and offset of the stance and swing phase at a good success rate.

Further research can be done in the signal processing to differentiate diseased case and non-diseased cases of human gait. The research may go in the direction to set a wireless interfacing between the PCB and computer.

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