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DESIGNING OF AN APPLICATION BASED CONTROL SYSTEM FOR ROBUST AND INTELLIGENT 1DOF EXOSKELETON

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ABSTRACT

The hi-tech developments that have been made in the Engineering and increasing demand of high performance work with least time taken has contributed rapid progression in digital control of motors; for aiding impaired humans. A number of different techniques have been utilized with the usage of different sensors including Torque sensor, Accelerometer, EEG, and EMG. But the new sensor has been developed which is capable of encoding the human muscular motion in to the Electric signal. The sensor essentially uses Polyvinylidene Flouride. Enactment of the System has been segregated in to two phases primarily. The Electric Signals which have been impregnated with the Human Muscular Motion Data; are to be procured firstly. Then the Motor Drive Circuit which augments and supports the Human's Limb Motion is to be energized; in correlation with the signals achieved after Conditioning. This concocted Application being less prone to Errors; sniffs and processes the Muscular Signals instead of the Neural Signals. As, The Polyvinylidene Flouride has been incorporated in such a genre that it is directly impacted with the Human Muscle. Hence, the designed System imparts the Super Human Facets at low cost not only to the Normal people but to the handicapped people as well.
So, this method is evaluated to check its feasibility as an adequate and economical solution.

Index Terms: Exoskeleton, Polyvinylidene Flouride, Brachial Muscle, Piezo Electric Co-Efficient, Degree of Freedom, Body Mass Index, Peripheral Interface Controller.

I. INTRODUCTION

In the former past, the Penicillin was discovered and then with the evanescent of time the Medical Field progressed to the development of X-Rays and subsequently to the conjectures of Human Parts Transplantation. For ameliorating mankind the Medical Field with its fusion to engineering especially Electrical; has excelled edictally and ascertained the animation of Humanoid Robots. Moreover, the Individuals especially handicapped people have been bolstered to the Fact that "THINK AND DO". They would only think the action in their mind and the signals would be fetched from their brain to the wireless Robot which would operate accordingly. Also, the Muscle movement of the Human would be dissected and if the intention of any action would be present then the Machinated Device would execute it likewise. Hence the Escalation in the Medical Field has made even an Immobilize Human not to devolve on others rather he would be enduring his life in the same genus as the Normal Human does. So, it is the need of an hour to concoct such contraption which involves the unique and optimal mechanism that would abet Halted Humans to Action; in such comportment that even a feeble feat of them would consequent a Stalwart Muscular Errand. The research paper at hand is about the designing of a wearable arm cover that alleviates the movement of arm. The title has the key word "Exoskeleton" that means an external machine that is intended to wear at the specific area over the body; which augments the muscular strength of the Humans. Moreover in this the Muscular movement of the Human would be dissected and if the intention of any action would be present then the Machinated Device would execute it likewise.

II. PRIME MOVER IN THE ELBOW

Let us first make an understanding of how does the Elbow execute any motion. As the degree of freedom of elbow is only one that is it cannot be moved without moving a shoulder so for the healthy person who is having Body mass Index value from 18.5 to 24.9 [1]; the Brachial Muscle which is 6.53 cm in length excluding tendon is responsible for the entire motion occurring in the elbow [3, 4] with support of other muscles like Brachii and Brachioradialis [2]. Hence it is to be evaluated then that what would be the threshold above which the force produced by the Brachial Muscle causes motion in the entire elbow. For this different classes have been introduced depending upon the factor that effective length and weight of forearm varies with right or left side, age and gender. In Fig: 1 the statistical data has been presented graphically.

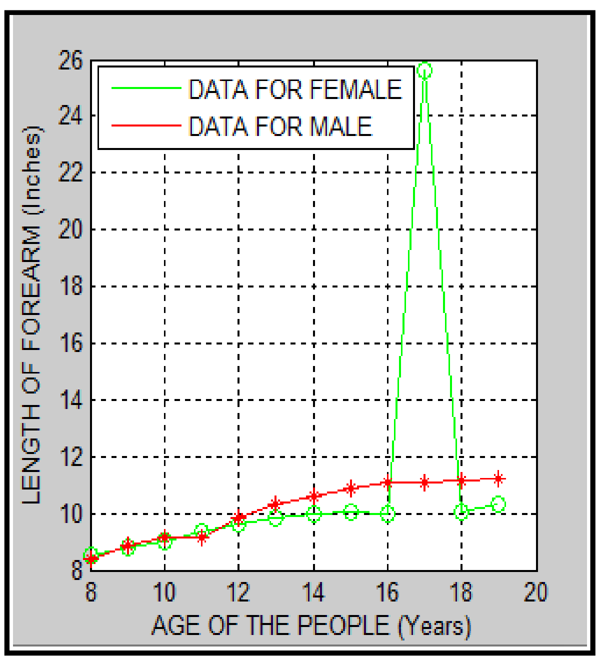

Fig: 1 Average Length of Forearm on the Basis of Age and Gender [8]

In the same way the quantitative data for different people having their respective forearms weight for each left and right side has been shown in Fig: 2 by Matlab simulation.

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Fig: 2 Weight of Different People's Forearm [8]

Hence to be more precise; the gathered data has been transformed in to the upper and lower bounds with deviation in them. For this an independent table has been shown which actually depicts the summary of the above mentioned graphs.

Table 1: Quantitative Analysis of Forearm [8]

Quantity	**Length (inches)**		**Weight (gm)**	
	Female	**Male**	**Left**	**Right**
Mean	9.625	10.161	1888.2	1113.3
Standard Deviation	0.539	0.957	298.88	271.09
Lower Limit	9.086	9.204	1589.32	842.21
Upper Limit	10.164	11.118	2187.08	1384.39

After having the data; the force produced by the muscle can be calculated through equation (1) in which first muscle torque is to be determined.

$$\text{Torque} = \text{Moment Arm} \times \text{Force} \quad (1)$$

And it is to be noticed that moment arm of the elbow especially for the Brachial Muscle would be the 0.42 percentage of the length of the forearm from the proximal end [6]. Hence Table 2 shows the calculated length of the forearm.

Table 2: Moment Arm Measurements [9]

Quantity	Length (m)		Moment Arm (m)	
	Female	Male	Female	Male
Lower Limit	0.2308	0.2338	0.097× 10-2	0.0982× 10-2
Upper limit	0.2582	0.2824	0.11× 10-2	0.12× 10-2

And the force in equation (1) would be determined by the following illustrated equation.

$$\text{Force} \quad = \quad \text{Weight of Forearm} \times \text{Gravitational Constant} \qquad (2)$$

Hence, the corresponding force values would be attained and have been shown in the following table.

Table 3: Force Measurements

Quantity	Weight (Kg)		Force (N)	
	Left	Right	Left	Right
Lower Limit	1.58932	0.84221	15.58	8.25
Upper limit	2.18708	1.38439	21.43	13.57

Now, from Table 2 and 3 we are in the position to calculate that value of torque which in return is used to calculate that threshold value of force that maintains the equilibrium condition in the arm as the Brachial Muscle length is 6.53 cm; by considering it as a moment arm the minimum value of force above which the elbow undergoes a motion would be calculated. The results have been shown in the graphical form in Fig 3.

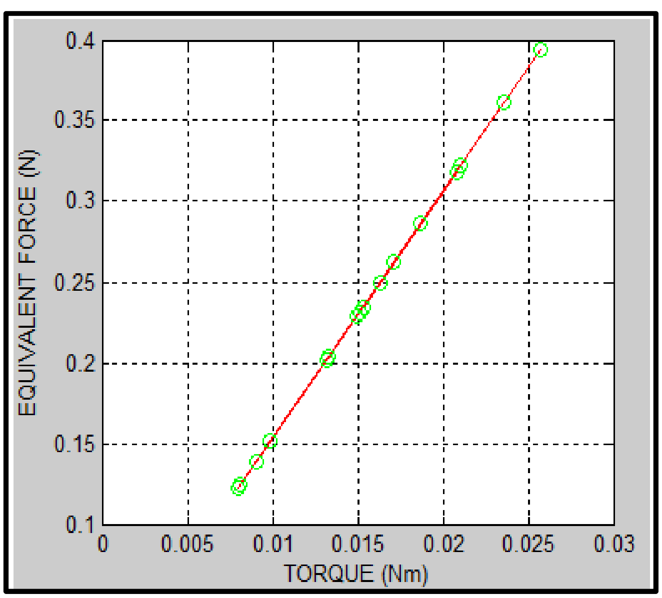

Fig: 3 Threshold Force Measurements [8]

III. ENCODING MUSCULAR MOVEMENT IN TO ELECTRIC SIGNAL

That value of force above which Brachial Muscle would allow the elbow to move has been calculated now; as the periphery has to be designed which senses this motion in the elbow and drives the motor driving circuit accordingly. It is the need of an hour to use that sensor which converts that mechanical motion of the muscle into the electric signals. Variety of sensors is available in this regard but each has its own limitation. The application is designed in such a way that the muscle would be directly impacted by the sensor to make design less prone to errors. Hence that material which has the nature of getting polarized with the exertion of force has to be searched and also keeping in mind the point that it would not be harmful to the muscle as it has to be stitched with it. Variety of piezo electric materials is available but their reliability factor is found to be poor. In Fig 4 the piezoelectric materials with their reliability factor has been shown.

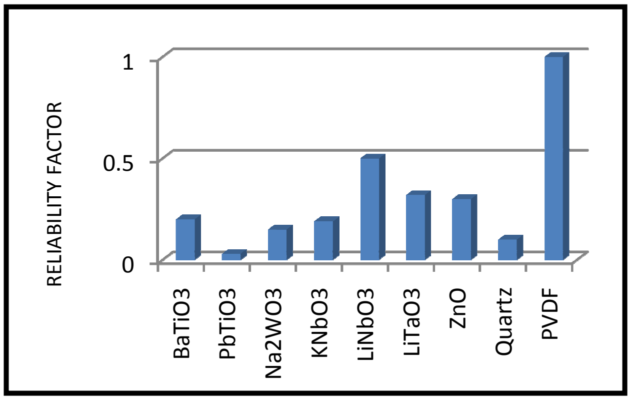

Fig: 4 Different Piezo Electric Materials

Hence, in this regard a polymer called as Polyvinylidene Flouride which is piezoelectric in nature and inert to all the chemical reactions occurring in the human body, is used. [5, 7] Moreover, acids like Amino Acids and Fatty Acids are also not reactive with this polymer and it efficiently gets polarize after experiencing force without harming human. With the application of 1 Newton force on PVDF the 22 pC charge is produced and it is the piezo electric co-efficient of PVDF. [7]

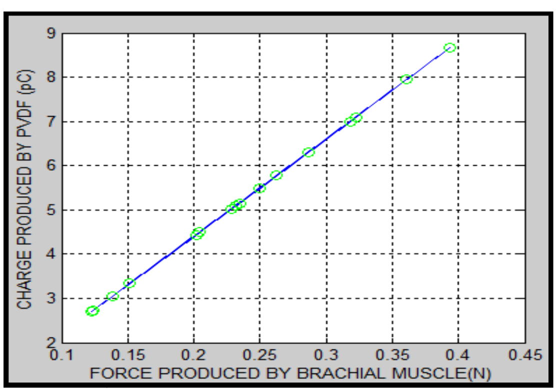

Fig: 5 Threshold Force Measurements [8]

The corresponding value of charge that PVDF produces can be calculated and is shown in the Fig: 5 in which the data from Fig 3 has been used.

PVDF being thin film in structure and plastic like white polymer [5] actually polarizes upon exertion of pressure on it but it is not conductor of the charge. Hence, the Brachial Muscle is to be stitched with human safe PVDF polymer by using the suture which is non absorbable in human body and also does not harm human that is Nylon suture.

The stitching style that would be used is the hemming one that the Brachial Muscle's 6.53 cm entire length would be covered with that equal length of PVDF films. Moreover, it is to be proposed that instead of using single film number of films must be used to increase the polarization because one film of larger area would decrease the value of piezo electric co-efficient that's why the front and back side of the Brachial Muscle would be stitched with very thin PVDF films. In this regard twelve films each having dimension of 0.2 cm X 6.53 cm would be used. And one thing to notice that for transference of charge from the PVDF to the motor driving unit the charge conductor which is again human friendly is to be wrapped at the ends of PVDF films. The metallic conductor proposed for this would be Gold.

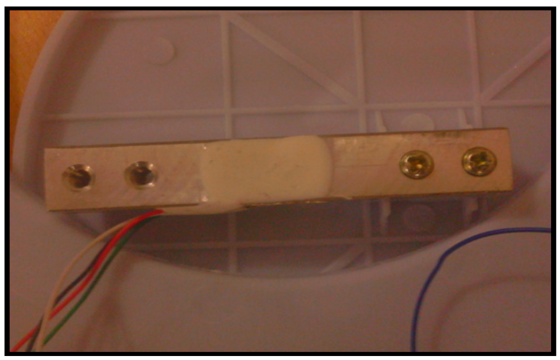

Fig: 6 PVDF Material used for Experimentation

For the experimentation sake, the Iron base has been fabricated with the white PVDF plastic material and when it experiences pressure then relative amount of charge produces in it which through the metallic base travels to the driving circuit. Fig 5 shows the PVDF assembly that has been used.

Moreover, it is necessary to mention here that the white plastic coating present on the front side of metal base; is also present at the back side of it. Hence, if one side undergoes expansion by applying stress then other side would equally contracts. That's why the waveform shown on the oscilloscope is Sine wave.

Frequency of this signal depends on the strain produced in PVDF when pressure is applied and on the capacitance of the material. In this case the PVDF used has the fixed capacitance 11.4 X 10^{-9} F [7].

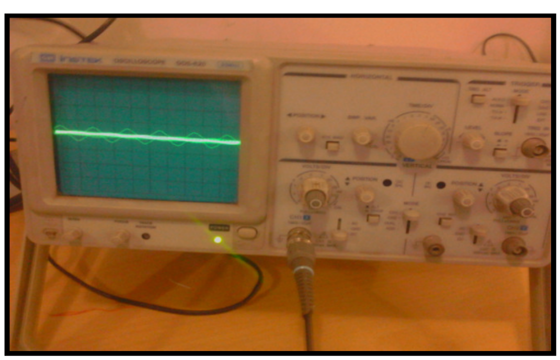

Fig: 7 Signal produced by PVDF

IV. SIGNAL CONDITIONING

The Brachial Muscle continuously executes the motion of contraction and expansion, the decision is to be made that either the charge produce by that muscle motion energizes the motor drive or not. So, firstly the voltage produce by this muscle through PVDF assembly would be calculated using the capacitance of the PVDF. Fig 8 shows the corresponding values of voltage produced for every class.

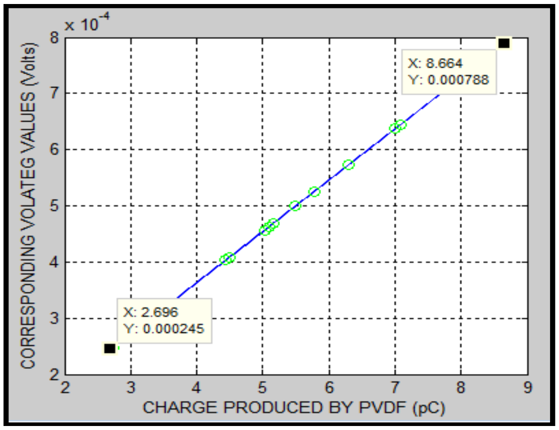

Fig: 8 Voltage Measurements for different Classes

From the above figure it can be seen that least value of the Voltages produced from the Muscle movement is 0.000245 Volts and the maximum value is 0.000788 Volts. As, these are the threshold voltages so, the electronic system has been designed for the Female's left Forearm Upper Limit voltage value which is 0.000463 Volts. Further more the usage of classes can facilitate to enter the required parameters in the system and then have the threshold values change accordingly. But now 0.000463 volts are the threshold at which the elbow remains in equilibrium. If elbow executes any motion then voltage production for this particular scenario would be increased from that threshold value.

So, two cascading Operational Amplifiers with weighted values resistors would be used which act as a comparator having reference value equal to that threshold value. Hence with the motion in elbow the output of that unit would be non–zero which then would be fed to the controller particularly 16F877A after passing through ADC for driving the motor drives that are meant to aid the motion of the elbow.

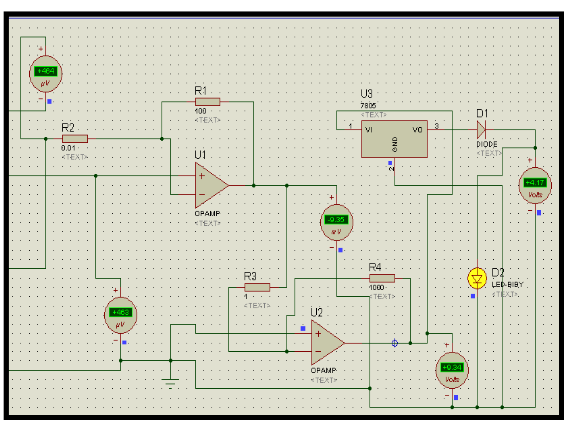

Fig: 9 Cascading Amplifiers Output

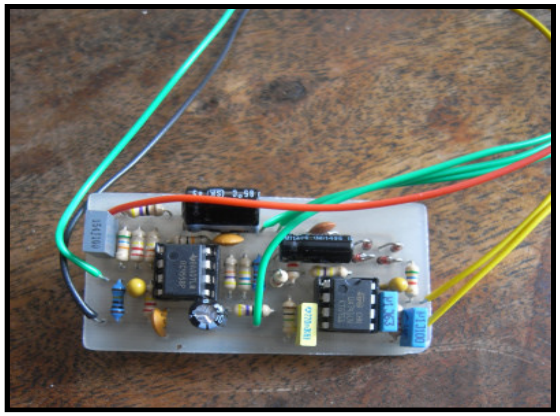

Fig: 10: Hardware of the Comparator Section

V. APPLICATION

In Past, wheelchairs were deployed and the buyers of them would only pay money to drag the chair by their hands for applying force to access any location with having zilch shove in their bodies. While God has not created Human for snuggling down for hours to an end, also; the Human Metabolism works properly if the body executes the motion and hence augments the Human Health. The Exoskeleton machine cover has been proposed on the Skeletal Strategy i-e the joints of Exoskeleton must be arrayed correspondingly with the joints of the Human body; on which it has been worn; by this pedagogy the force exerted by the exoskeleton is thus impacted directly on the joints of the Human hence amplifying the supremacy of the motion. It can be incorporated in the Military Activities by the Soldiers having it on their body; hence letting them to carry heavy objects even while running or climbing stairs, in the consequence of that the soldier would not only potentially carry more weight but also he could presumably wield heavier weapons and armour. Thus they can brazen out their enemies in the better way. [3] Furthermore it vindicated that its usage can be asserted in the Rehabilitation of the Stroke patients.

VI. CONCLUSION

Pedomotor, Hardiman, Pitman the Humanoid Robots can be overcome by this designed application. As, it is not too much heavy and big in size rather it could easily be coped in any condition. Moreover, the sensor use in it is not that much costly as the sensors like Electromyogram, Electroencephalography is. Also, it is not viable to have such discrepancies like Bending Tendency of Exoskeleton, Bifurcation of Reflexive and Premeditated Action, Pilfering of the User Skin. The devised method is not only cost effective but also easy to implement having simple control processes & inter-working circuits vis-à-vis intelligent based motor drive. The scheme can easily be included in digital drive software of the industrial projects for prospective future research work.

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