ISSN (Online) : 2454-7190 **ISSN 0973-8975**

J.Mech.Cont.& Math. Sci., Vol.-11, No.-2, January (2017) Pages 23-36

HIGH DOF INTERPRETED EMG DATA BASED PROSTHETIC ARM

By

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https://doi.org/10.26782/jmcms.2017.01.00003

Abstract:

EMG is the detection of the electrical activity associated with muscle contraction. It is obtained by measurement of the electrical activity of a muscle during contraction. EMG signals are directly linked to the desire of movement of the person. Robot arms are versatile tools found in a wide range of applications. While the user moves his arm, (EMG) activity is recorded from selected muscles, using surface EMG electrodes. By a decoding procedure the muscular activity is transformed to kinematic variables that are used to control the robot arm. This patent is the innovative design of a new low-cost series elastic robotic arm. The arm is unique in that it achieves reasonable performance for the envisioned tasks with high DOF. There are numerous dimensions over which robotic arms can be evaluated, such as backlash, payload, speed, bandwidth, repeatability, compliance, human safety, and cost, to name a few. In robotics research, some of these dimensions are more important than others: for grasping and object manipulation, high repeatability and low backlash are important. To develop the articulated innovative arm design of the robot with high DOF equations were developed for both forward and inverse kinematics. Forward kinematics gives the location of the end effector in the "universe" frame. The inverse kinematics gives the joint angles needed in order for the to the robot arm reach the goal frame. This high DOF based prosthetic arm operates according to EMG database. The EMG signal is obtained for different users for different arm movements using signal acquisition system. The EMG signals are used as input to the Microcontroller and converted to digital ones in the comparator. According to these signals the program built in the microcontroller make decisions to control the motors to drive the prosthesis arm.

Keywords : EMG signals, Robot arm, high DOF, Microcontroller comparator, Prosthetic arm

I. Introduction

In order to give rehabilitation to amputees, Prosthesis is one of the best solutions. Prosthesis means the replacement of a missing body part with an artificial substitute. It consists of mechanical parts and a processor to control it. The controller processes the sEMG signals from the residual muscles and controls the movement of the mechanical parts by employing real-time learning. The prosthesis is designed with basic movement and grabbing features, the design has been done with care so that it can be extended to other hand-movements. This unique prosthesis arm , controlled by Knowledge based database of EMG signal will perform the same movement as original arm does. To generate the knowledge based data base we have used five moments of arm for EMG signal acquisition. The movements are Extension of forearm, Flexion of elbow joint ,Pronation of forearm, Wrist flexor stretch &Shoulder abduction. The database is mainly consists of various interpretation techniques like envelope detection, spectrogram analysis, quantization,power spectral density analysis etc. for any particular movement of original arm, the high DOF based prosthetic arm will do the same. To obtain a high degree of freedom four servo motors are used and one extra motor for overall orientation. Servo motors are rotary actuators that allows for precise control of angular position, velocity and acceleration. It consists of a motor coupled to a sensor for position feedback. Servomotors are used to control wrist motion. It can be moved in desired direction by sending PWM signals from microcontroller to the control wire of prosthetic wrist. The width of the pulse determines the angular position. In order to create a prosthetic arm capable of natural movement it is necessary to mimic both the sophisticated system and intricate interactions between them. This can be achieved by using actuators, microcontroller embedded software.

II. Objective

- This innovative model is completely controlled by EMG Data base. Which is pure raw EMG data. We have prepared a knowledge based database of EMG Signal for different arm movements which will be used to analyze the acquired EMG Signal.
- This high DOF prosthetic arm is totally controlled by EMG Data base. For interpreting the EMG signal different characterization techniques have been used like spectrogram analysis, envelope detection,sampling,quantization and power spectral density analysis. Beside these this knowledge based database has been produced by using some different weights like 2kg,4kg for different movements including four muscles of our body.
- This unique model consists of four motors but one extra motor is used for overall orientation. For this reason high DOF based prosthetic arm is possible to design which

will show that for every arm movements our innovative prosthetic arm will exactly do the same movements.

- This prosthetic arm will help the handicapped people necessarily by acquiring the EMG signal from their body. With this high DOF based prosthetic arm original arm will be replaced by this and will move exactly as an original arm.
- Highly intelligence is obtained with this arm because the holding power of this arm is same as an original arm.

III. System Controlled Block Diagram

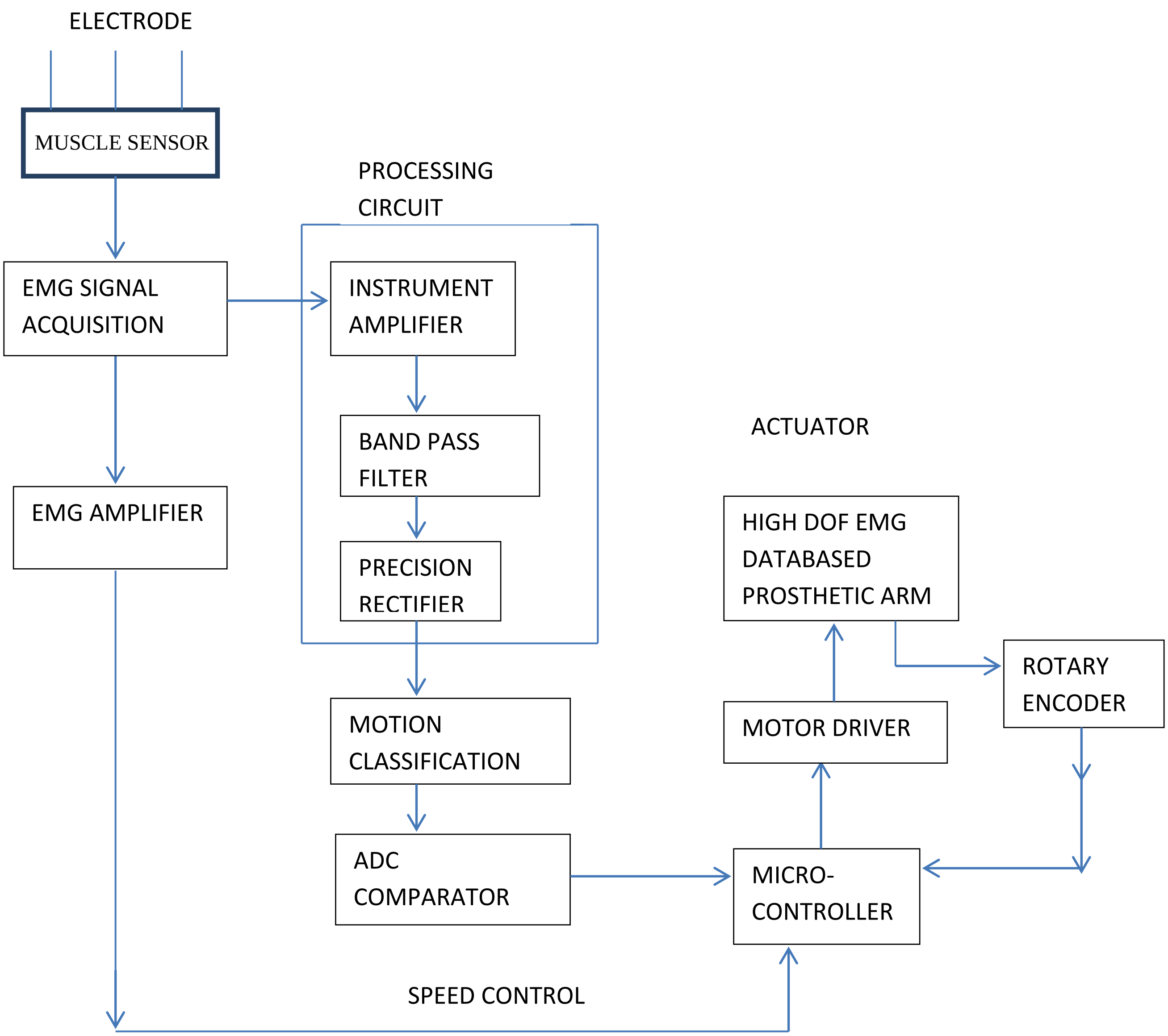

Fig : 1Block diagram of high DOF interpreted EMG data based prosthetic arm

This is the entire block diagram of high DOF based EMG interpreted prosthetic arm. This innovative arm is prosthetic because it does the steps exactly what an original hand can do. A person's prosthesis should be designed and assembled according to the patient's appearance and functional needs. For instance, a patient may need a transradial prosthesis, but need to choose between an aesthetic functional device, a myoelectric device, a body-powered device, or an activity specific device. The patient's future goals and economical capabilities may help them choose between one or more devices.These hands were completely revolutionary in their look and function compared with other prosthetic options that existed. It consists of three main sections from which view this block diagram is developed.

1. Biomedical-
   need to know what part of the brain would be used to send those signal to the arm
   Where to place the electrodes on your body
   How much strain it would put on your body
2. Mechanical
   Have to design how the arm moves
   Figure out how much weight could be put onto the machine/ motor
3. Electrical
   Need to set up all the wiring for the arms

The above fig shows a block diagram of the myoelectric ally controlled partial-hand prosthesis system. The electrodes are attached to the biceps. Biceps consist of bundles of skeletal fibers. When the fibers extend along the length of the muscle, the extracellular field potential is evoked. The extracellular field potential is an EMG and has a brief duration of 3–15 ms. The typical amplitude of EMG ranges from 20–2000 μV, depending on the size of the motor unit and the position of the electrode. The EMG signals generated from a contracting muscle and detected by physiological signal electrodes are first sent to the instrumentation amplifier, the band pass filter, and the precision rectifier circuits. Following amplification, filtering, and rectification, the resulting signals are used as inputs to the microcontroller and are converted to digital ones by a 1-b analog comparator embedded in the microcontroller. According to the digital signals, the program built in the microcontroller can make precise decisions and then output PWM signals to control the R/C servomotor to drive the prosthesis. After several iterations of pretesting electrode efficiency, passive electrodes were adopted in this project for economy and convenience. The selected electrodes must meet the following requirements:

1. include conductive adhesive hydrogel; 2) have a high-quality foam substrate that resists fluids and conforms easily to the skin, to ensure excellent trace quality; 3) be small for convenient lead placement; 4) be teardrop-shaped for easy release and removal; 5) have a perforated liner that allows the electrodes to be divided into strips; 6) support multiple packaging configurations. The

Burr–Brown INA-118P amplifier is used as a first stage differential amplifier with a gain of 20.

This amplifier exhibits a high common-mode rejection ratio (CMRR) and effectively reduces noise. A band pass filter with gain =150, consisting of a high-pass and a low-pass filter, was designed with a low power op amp LF351 (National Semiconductor). The cutoff frequency of the lowpass filter was 500 Hz while that of the high-pass filter was 50 Hz. Meanwhile, the total gain of the combination of the instrument amplifier and the band pass filter was 20x150. This gain is high enough to amplify the obtained EMG. A servomotor commonly used for control applications consumes much current and is oversized and expensive. Because a stepping motor loses step under some conditions, it unsuitable in this application. Besides, servomotors and stepping motors must be controlled by external driver circuits. The R/C servomotor is controlled by a PWM signal, which can drive the motor to a desired position according to the width of the pulse. Given a 0.5–2.5-ms pulse width, the R/C servomotor can rotate from – 900 to + 900 clockwise. The output shaft of the servomotor can drive the linkage so that the movable part of the prosthesis rotates with respect to the swivel and then closes the palm of the prosthesis. The output torque of the servomotor is approximately 3 kg-cm so that the designed prosthesis can easily grasp an object that weights 1 kg.

IV. Circuit Approach Application

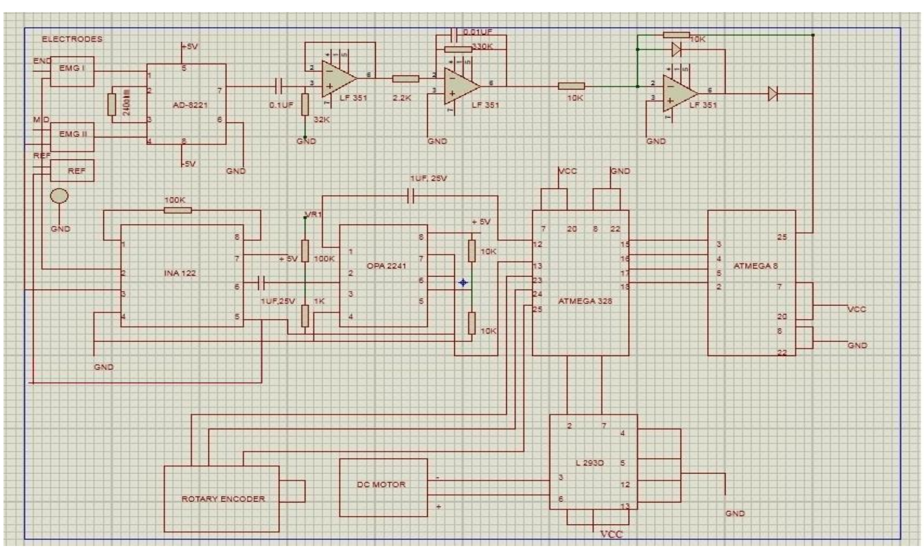

Fig : 2 Circuit approach implementation of high DOF interpreted EMG data based prosthetic arm

Prosthesis is an artificial extension that replaces a missing body part. Prostheses are typically used to replace parts lost by injury or missing from birth or to supplement defective body parts. . One of the main requirements of artificial arm is that functionally, it should be as near to the natural hand as possible. This unique arm is high DOF based, will control the missing arm as well as original arm. Extra one motor is there to control the overall orientation. The intended action of the arm is understood from the EMG signal parameters which are obtained by using defined circuit scheme. The pulses are generated by using microcontroller and the respective motor is driven for movements of the hands and wrist, viz . hand open, hand close, wrist flexion, wrist extension, extension of forearm, shoulder abduction etc. among of these specified movements we have used five selected movements like Extension of forearm Flexion of elbow joint, Pronation of forearm, Shoulder abduction, Wrist flexor stretch. A knowledge based data base has already been produced through which we can interpret the EMG signal and move our high DOF based prosthetic arm.

From the circuit approach implementation point of view the selected electrodes have met the following devices. The **LF351** is an op amp with an internally trimmed input offset voltage and JFET input devices. These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore, large differential input voltages can easily be accommodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit. Exceeding the negative common-mode limit on either input will force the output to a high state, potentially causing a reversal of phase to the output. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode. Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state. The amplifier will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur. The LF351 is biased by a zener reference which allows normal circuit operation on ±4V power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate. The LF351 will drivea2kΩ load resistance to ±10V over the full temperature range of 0˚C to +70˚C. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings. Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit. As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in orderto ensure stability. For example, resistors from the output toan input should be placed with the body close to the input tominimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground. A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

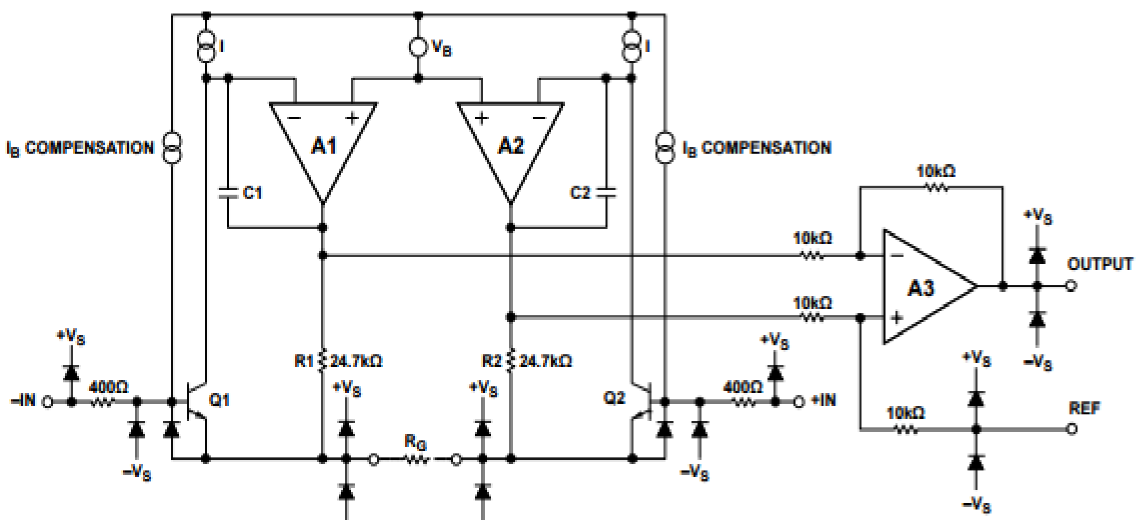

Fig : 3 Schematic of AD 8221

The AD8221 is a gain programmable, high performance instrumentation amplifier that delivers the industry's highest CMRR over frequency in its class. The CMRR of instrumentation amplifiers on the market today falls off at 200 Hz. In contrast, the AD8221 maintains a minimum CMRR of 80 dB to 10 kHz for all grades at G = 1. High CMRR over frequency allows the AD8221 to reject wideband interference and line harmonics, greatly simplifying filter requirements. Possible applications include precision data acquisition, biomedical analysis, and aerospace instrumentation.Low voltage offset, low offset drift, low gain drift, high gain accuracy, and high CMRR make this part an excellent choice in applications that demand the best dc performance possible, such as bridge signal conditioning. Programmable gain affords the user design flexibility. A single resistor sets the gain from 1 to 1000. The AD8221 operates on both single and dual supplies and is well suited for applications where ±10 V input voltages are encountered. The AD8221 is available in a low cost 8-lead SOIC and 8-leadMSOP, both of which offer the industry's best performance. The MSOP requires half the board space of the SOIC, making it ideal for multichannel or space-constrained applications. Performance is specified over the entire industrial temperature range of −40°C to +85°C for all grades. Furthermore, the AD8221 is operational from −40°C to +125°C. The AD8221 is a monolithic instrumentation amplifier based on the classic 3-op amp topology. Input transistors Q1 and Q2 are biased at a fixed current so that any differential input signal forces the output voltages of A1 and A2 to change accordingly. A signal applied to the input creates a current through RG, R1, and R2, such that the outputs of A1 and A2 deliver the correct voltage. Topologically, Q1, A1, R1 and Q2, A2, R2 can be viewed as precision current feedback amplifiers. The amplified differential and common-mode signals are applied to a difference amplifier that rejects the common-mode voltage but amplifies the differential voltage. The difference amplifier employs innovations that result in low output offset voltage as well as low output offset voltage drift. Laser-trimmed resistors allow for a highly accurate in-amp with gain error typically less than 20 ppm and CMRR that exceeds 90 dB (G = 1). Using superbeta input transistors and an IB compensation scheme, the AD8221 offers extremely high input impedance, low IB, low IB drift, low IOS, low input bias current noise, and extremely low voltage noise of 8 nV/√Hz. The transfer function of the AD8221 is $G = 1 + \frac{49.4\,K}{R_G}$. A unique pin out enables the AD8221 to meet a CMRR specification of 80 dB at 10 kHz (G = 1) and 110 dB at 1 kHz (G = 1000). The balanced pin out, shown in Figure 44, reduces the parasitics that had, in the past, adversely affected CMRR performance. In addition, the new pin out simplifies board layout because associated traces are grouped together. For example, the gain setting resistor pins are adjacent to the inputs, and the reference pin is next to the output.

In the hardware part there is The **ATmega 328** is a single chip micro-controller created by Atmel and belongs to the megaAVR series. The Atmel 8-bit AVR RISC-based microcontroller combines 32 KB ISP flash memory with read-while-write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible timer/counters with compare modes, internal and external interrupts, serial programmable USART, a byte-oriented 2-wire serial interface, SPI serial port, 6-channel 10-bit A/D converter (8-channels in TQFP and QFN/MLF packages), programmable watchdog timer with internal oscillator, and five software selectable power saving modes. The device operates between 1.8-5.5 volts. The device achieves throughputs approaching 1 MIPS per Mhz.Today the ATmega328 is commonly used because of its simple, low-powered, low-cost micro-controller is needed.

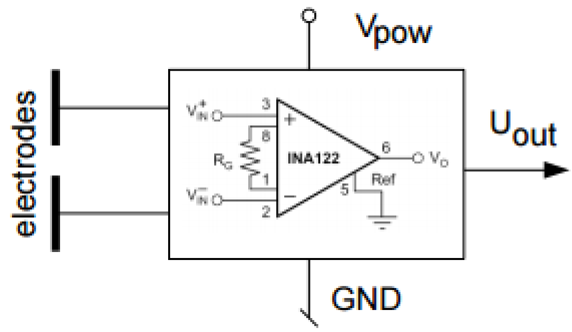

Fig : 4 Block diagram of control system for prosthetic control

The **INA122** is a precision instrumentation amplifier for accurate, low noise differential signal acquisition. Its two-op-amp design provides excellent performance with very low quiescent current, and is ideal for portable instrumentation and data acquisition systems. The INA122 can be operated with single power supplies from 2.2V to 36V and quiescent current is a mere 60µA. It can also be operated from dual supplies. By utilizing an input level-shift network, input commonmoderange extends to 0.1V below negative rail (single supply ground). The application of the INA122 amplifier was a result of searching for solution in which the simple amplifier for microcontrollers platform can be found. The microcontroller should get EMG signal without noise and process it.The EMG signal processing can provide information contained in the raw signal. This process can be realized by microcontroller. The location of electrodes, skin preparation and other factors can all affect the results. Even the activity or inactivity of muscle must noticeably change the signal, so the signal should be suitable amplified. The change of the EMG signal involves the expression of the amplitude of the signal as a ratio to the amplitude of a contraction and change of values of amplitude are various for different frequency of signal. The main task for the amplifier is to provide the signal of a level suitable for A/D converter and in consequences for the microcontroller. basic properties: low power consumption and small dimensions and also must include components shown on Fig. The amplifier should provide the proper gain to measure the EMG signal and also its sensitive to get information about small activity of the muscle recorded as a change of output voltage accepted by predicted type of A/D converter. Very good property of the amplifier INA122 is the possibility to apply a single voltage. In all experiments the 5[V] Vpow=[V] of supply voltage was used. The selection of supply voltage was based on that many microcontrollers work in range from 3.3[V] to 5[V]. For INA122 the gain can be regulated by external resistor. For experiments the gain was assumed on level 1000 [V/V]. The power was provided by a set of batteries in order to eliminate the interferencegenerated from the electricity grid.

L293D is a Motor driver integrated circuit which is used to drive DC motors rotating in either direction. It is a 16-pin IC which can control a set of two DC motors simultaneously. The L293D uses 5V for its own power and external power source is needed to drive the motors, which can be up to 36V and draw up to 600mA. The L293D on each side, dedicated to the controlling of a motor. There are 2 INPUT pins, 2 OUTPUT pins and 1 ENABLE pin for each motor. LH-bridge is given this name because it can be modeled as four switches on the corners of 'H'. The basic diagram of H-bridge is given below :L293D consist of two H-bridge. H-bridge is the simplest circuit for controlling a low current rated motor.

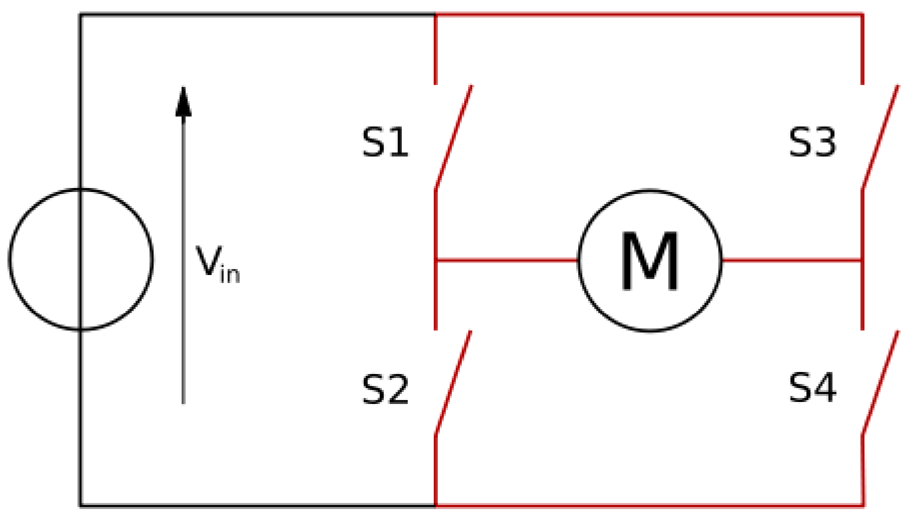

Fig :5 H bridge circuit

In the given diagram, the arrow on the left points to the higher potential side of the input voltage of the circuit. Now if the switches S1 & S4 are kept in a closed position while the switches S2 & S3 are kept in a open position meaning that the circuit gets shorted across the switches S1 & S4. This creates a path for the current to flow, starting from the V input to switch S1 to the motor, then to switch S4 and then the exiting from the circuit. This flow of the current would make the motor turn in one direction. The direction of motion of the motor can be clockwise or anti-clockwise, this is because the rotation of the motor depends upon the connection of the terminals of the motor with the switches. For simplicity, lets assume that in this condition the motor rotates in a clockwise direction. Now, when S3 and S2 are closed then and S1 and S4 are kept open then the current flows from the other direction and the motor will now definitely rotates in counter-clockwise direction When S1 and S3 are closed and S2 and S4 are open then the 'STALL' condition will occur(The motor will break). Stall Condition: When the motor is applied positive voltage on both sides then the voltage from both the sides brings the motor shaft to a halt.

The **OPA241** series and OPA251 series are specifically designed for battery powered, portable applications. In addition to very low power consumption (25μA), these amplifiers feature low offset voltage, rail-to-rail output swing, high common-mode rejection, and high open-loop gain. The OPA241 series is optimized for operation at low power supply voltage while the OPA251 series is optimized for high power supplies. Both can operate from either single(+2.7V to +36V) or dual supplies (±1.35V to ±18V). The input common-mode voltage range extends 200mV below the negative supply—ideal for single-supply applications. They are unity-gain stable and can drive large capacitive loads. Special design considerations assure that these products are easy to use. High performance is maintained as the amplifiers swing to their specified limits. Because the initial offset voltage (±250μV max) is so low, user adjustment is usually not required. However, external trim pins are provided for special applications (single versions only). The OPA241 and OPA251 (single versions) are available in standard 8-pin DIP and SO-8 surface-mount packages. The OPA2241 and OPA2251 (dual versions) come in 8-pin DIP and SO-8 surface-mount packages. The OPA4241 and OPA4251 (quad versions) are available in 14-pin DIP and SO-14 surface-mount packages. All are fully specified from –40°C to +85°C and operate from –55°C to +125°C.

Rotary encoders track motor shaft movement for myriad pieces of industrial equipment and commercial devices. For industrial applications, incremental encoders (used when only relative position is needed, or cost an issue) are typically used with ac induction motors. In contrast, absolute encoders (which give a different binary output at each position, so shaft position is absolutely determined) are often paired with permanent-magnet brushless motors in servo applications. Often, encoder feedback is used to ensure synchronization of the motor stator and rotor positions to drive-supplied current, so current is applied to the windings when the rotor magnets are within a proper position range (to maximize torque.)Encoders can be used in applications, where length,positions, speed or an angular position are measured.They transform mechanical movements intoelectrical signals and can be divided into incrementaland absolute measuring systems.Incremental encoders generate pulses, where thenumber of pulses can be a measure of speed, lengthor position.In absolute encoders, every position corresponds toan unique code pattern, so that even after a powercut the actual position is recognized, when power isre-applied.

V. Model Art of Design

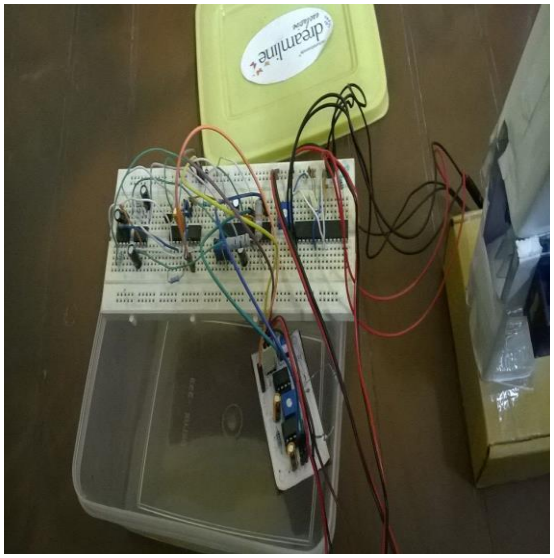

Fig : 6 Internal circuit diagram   Fig : 7 Apart of high DOF interpreted EMG data based prosthetic arm

Fig : 8 Prosthetic arm is moving same as the man is doing

The objective of this innovative work was to design and construct a prosthesis arm with high DOF that will be strong and reliable, while still offering control on the force exerted. The design had to account for mechanical and electrical design reliability and size. These goals were targeted by using EMG in the electrical control system and a linear motion approach in the mechanical system .The signals recorded by the surface electrodes are sufficient to control the movements of a virtual prosthesis. Myoelectric prosthetic hand enables the user to enact a simple grasp with strength proportional to the contraction of certain muscle group. This unique device describes the design features of artificial hands that are lightweight, compact and dexterous, that mimics human anatomy and maintain a high lifting capability. These Myoelectric signals (MES) can be read by Myoelectrodes and amplified to measure a muscle‘s naturally generated electricity. After processing via designed processing units, these signals can be designated to control a particular and high degree of freedom(DOF) in the prosthesis. Many researchers are working in the development of prosthetic devices to aid the physically challenged people in their routine activities. Active prosthetics devices provide functionality in addition to structural support in place of missing limbs . Myoelectric or electromyogram (EMG) signals that may be acquired using suitable sensors from the human body are widely used in actuating prosthetic devicesby intelligently recognizing the intended limb motion of the person. EMG signals may be captured either from the surface of the skin using surface electrodes or from the muscles.

In the above figure the electrodes and the references are shown which is used for EMG signal acquisition. Then there is shown a small part of prosthetic hand which is controlled by the circuit that we have developed and doing the same gripping as the original hand of the man doing.

VI. Conclusion

This paper covers the details of the steps followed in designing prosthetic arm with high DOF. Above method and system is an original contribution to the investigation of new prosthesis control method which is completely controlled by EMG data base. The effect and role of every step in designing prosthetic arm has been explored. Several techniques have been developed to control multifunctional prosthetic devices, and many of them showed promising result. Moreover, these techniques could be also applied in other fields, not only in the control of myoelectric prosthesis.

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