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Biopotentials (EMG) based Artificial Arm

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ABSTRACT: It is a known fact that most of the people suffer from some kinds of disabilities, which are caused due to unexpected accidents taking place in their life. Some of such accidents cause the loss of body parts above the chest level called upper limbs. One of such parts is the hand. People who lose their hand due to accident or some other reason find it very uncomfortable even with the help some prosthetic device such as an ordinary arm to perform various operations that a normal arm does. Hence research has been going on in this field for providing an arm, which can function as a normal arm.

The artificial limb (hand) present now a day's can be broadly classified into three categories including a normal arm, an electric arm and a myoelectric arm. Of all these three, myoelectric arm is supposed to be the arm that is nearest to normal human arm. Here the signals from the left over part of the amputation are taken and are used to drive the electronic circuitry which helps in grasping and releasing of objects that are done by a normal arm.

Keywords: Biopotentials, EMG, Myoelectric and Electrodes

I. INTRODUCTION

The prosthetic hand is now much more than just a cosmetic limb that evens out the appearance of the human body. Modern technology has made it possible for this prosthesis to mimic a fully functioning human hand. Reasons for amputation include cardiovascular disease, traumatic accidents, infection, tumors, nerve injury and congenital anomalies.

Available prosthetic hands can only grasp and open. There are large differences among human hands operating complicated tasks flexibly. Amputees and the fields of rehabilitation medicine and welfare have waited for more useful and more bio-mimetic prosthetic hands.

This prosthetic hand uses Electromyogram (EMG) for presuming the amputee's intention. EMG is biopotential signal measured on a skin surface when a muscle contracts. It can be generated from amputee's partially lost muscle. The prosthetic hand controller measures an EMG signals when the amputee images the motion of the lost hand, presumes the motion, and controls the hand.

Additional sensors can be placed on an existing prosthesis to have the amputee regain partial feeling (hot or cold). Thick-film fabrication will allow multiple robust and compact sensor types to be deposited at a relatively low-cost. Force sensors based on thick-film piezoresistive material; slip sensors that exploit the piezoelectric behavior in specially formulated screen printable films and temperature sensors that are made from thick-film thermistors. The sensors will be characterized on a variety of different substrate materials so that the optimum combination can be selected for inclusion within the hand.

Cineplasty is the surgical fitting of a lever to a muscle in an amputation stump to facilitate the operation of an artificial hand. It is also the surgical isolation of a loop of muscle of chest or arm, covering it with skin, and attaching to it a prosthetic device to be operated by contraction of the muscle in the loop.

II. HISTORY OF PROSTHESIS

The concept of prosthetic limbs can be traced back to the 1500's, where these primitive artificial body parts were no more than sticks or stiff material strapped to the appropriate part of the body using archaic fastening methods.

In 1816 the Anglesea or clapped leg was developed for the First Marquess of Anglesea after he lost a limb during the battle of Waterloo the previous year – the latter name was given for the noise it made on full extension.

After World War 2, with the huge increasein young amputees, the need for better limb control became more apparent. This led to technology being concentrated on developing a new knee that would stablise during weight bearing but swing freely during walking.

The 1970's then saw the development of 'Modular Assembly Prosthesis' which allowed the assembly of a prosthesis from a series of stock components. Then, in the 1980's, with the development of materials in the aircraft industry, the world's first carbon fibre prosthetic system was made. This technology promoted high strength and light weight system.

Then in the 1990's, development into the first commercially avaliable microprocessor controlled prosthetic knee was carried out. Called t he intelligent prosthesis (IP), the unit is programmed to each individual user during walking to achieve the smoothest, energy saving pattern. It reacts to speed changes but its intelligence does not extend to understanding environmental considerations such as stairs, ramps or uneven terrain.

III. TYPES OF ARTIFITIAL ARMS

Various types of artificial arms have been reported in the literature.

Mechanical Arm:

These devices are functional prostheses that use some motion of the body to exert the force needed to control the prosthetic component. Of particular note is the Bowden cable for use in the prosthetics field. These cables, named after their inventor, have found extensive use in prosthetic applications. A Bowden cable consists of an inner core cable that is free to move within a sleeve cable which is fixed in place at either end. These devices require a harness, to be worn about the shoulders, to which one or more Bowden cables are attached.

The conventional below elbow, body-powered prosthesis has a single control cable that runs from the harness to a terminal device. Terminal-device opening and closing is then controlled by shoulder shrug and/or flexion of the residual upper arm.

For an above-elbow amputee an additional control cable is used to switch control of the harness from terminal device opening to elbow flexion by unlocking the elbow.

Body powered prostheses are the most common kind of prosthesis used all over the world. The reason for their success is due to the intimate connection the control cable provides between the input and output.

Electrical Arms

These are externally powered devices and receive their power from an electric external to the body. These are a relatively new (last 15 to 20 years) addition to the armamentarium of prosthetic devices.

Fig. 1. Electrical Arm.

Hybrid Arm

When body-powered and externally powered systems are linked together they are called hybrid systems. Hybrid systems are used most frequently with persons who have amputations above the elbow or who have bilateral arm amputations. Such systems can provide the user with the high gripping and/or high lifting capacities of powered systems and the fine control of body power. An example of hybrid control is illustrated in prosthetic limbs for persons with loss of both arms at the shoulder level. By providing the amputee with a body-powered limb on one side and an electric-powered limb on the other side, they enable the wearer to use the limb that is most appropriate for a specific task.

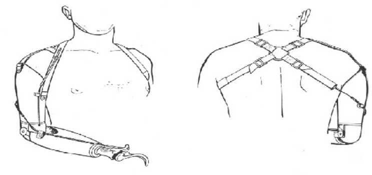

Fig. 2. Hybrid Arm.

This method also enables the limbs to be operated independently of each other i.e. the body motions required to operate the body-powered side do not influence the state of the powered limb and vice versa; they are decoupled.

Myoelectric Arm

The electrically powered prostheses under the control of myoelectric signals from residual muscles did not become commercially available until late 1960s and did not gain widespread clinical acceptance until the early 1980s. Myoelectrically controlled upper limb prosthesis offers the highest level of rehabilitation available today.

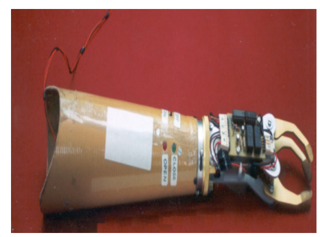

Fig. 3. Myo-electric Arm

Myoelectric control derives its name from the Electromyogram (EMG) signal, which is produced by a muscle when it contracts.

IV. EMG ANALYSIS

Electromyography is the process by which an examiner puts a needle into a particular muscle and studies the electrical activity of the muscle. This electrical activity comes from the muscle itself – no shocks are used to stimulate the muscle. The EMG also differs from the NCS because it does not involve actually testing nerves. However, you do get information indirectly about the nerves by testing the muscles. Eletromyographic testing involves evaluation of electrical activity of a muscle and is one of the fundamental parts of the electro diagnostic medical consultation.

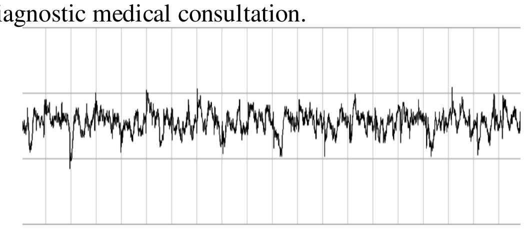

Fig. 4. Relaxation of muscle.

EMG is usually recorded by using surface electrodes or more often by using needle electrodes, which are inserted directly into the muscle.

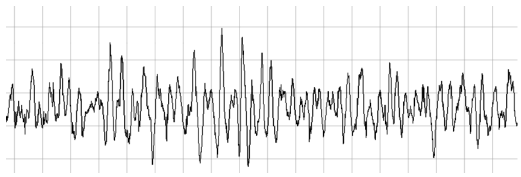

Fig. 5. Contraction of muscle.

A typical EMG signal ranges from 0.1 to 0.5mV and it contains frequency components extending up to 10 kHz.

The amplitude of the EMG signals depends upon various factors which are:

- The type of electrodes
- Placement of electrodes
- Degree of muscular exertions

Properties of EMG Signal:

EMG signal is generated by human muscle whenever it is activated. Frequency and amplitude of the signal changes based on the muscle's location within the body and the stress it undergoes. The signal is random, very small in amplitude and mixed with noise of different frequencies. The signal level is of the order of 0.5 mV for needle electrodes. For surface electrodes, it is in micro volts appearing on the skin surface of the major skeletal muscles. Its frequency spectrum is in the range of about 15 Hz -500 Hz with most of the signal energy concentrated around 100 Hz. Aligning the electrodes along the muscle length close to each other results in an increase of higher frequency contents. Electrode impedance should be as low as possible but not more than 2 KΩ. The signals taken from human arm muscle are shown in Figure during both relaxation and contraction of muscle.

Placing of Eletcrodes:

For proper signal acquisition, electrode placing on the arm is very important. This requires accurate identification of the muscle.

After thorough study and experimentation, three flexor and extensor muscles of the residual limb ***Anconious, Pronator teres & Brachioradials*** were identified from which appreciable signal was obtained during contraction.

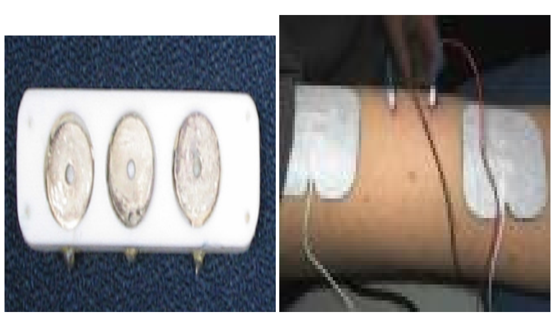

Fig. 6. Placement of Electrodes.

Three gold plated surface electrodes were mounted above these muscles - one as reference electrode, another as active electrode and the third as ground electrode. The difference signal between reference and active electrode is processed to reduce noise in the system. For better contact between electrode and muscle, we used a jelly type conducting solution. It took great effort to optimally place these electrodes and to identify the proper point of axial spread of muscle where the amplitude of signal was maximum.

The electrode assembly can not be placed axially along the muscles of the arm because the stump length available from such patients is not enough. The placement of this assembly in the transverse direction led to the difficulty that the surface of arm was not uniform throughout the radial span of the stump; it was rather curved. Also at the time of relaxation and contraction of the muscle, this curvature varies and the electrodes could not be fixed properly to pick the signal from a particular point. During experiments with this assembly, it was noted that if electrodes are placed very close to each other, active and reference electrodes pick up almost the same signal from the same muscle causing no difference between them.

V. ARM DRIVING CIRCUITARY

Block Diagram of the Sysem:

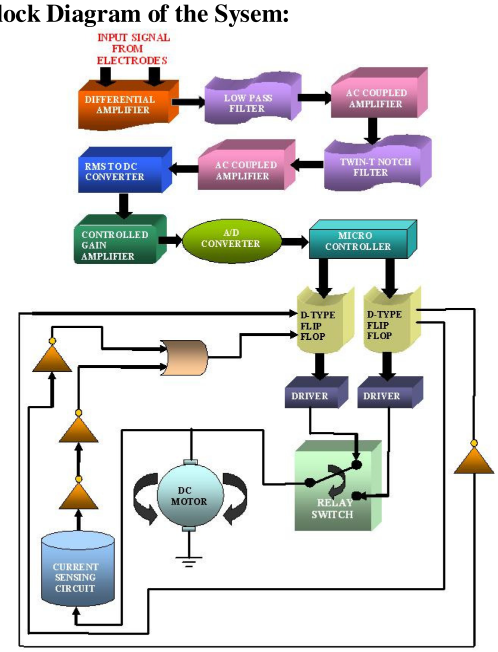

Fig. 7. Block Diagram of the System.

System Components:

- Electrodes
- EMG signal processing
- Artificial Arm
- Microcontroller
- Relay
- Motor unit

Electrodes:

Device that converts ionic potential into electronic potentials are called electrodes. Electrodes are such type of tools by which we can measure bioelectric events. All electrodes have the metal electrolyte interface.

Fig. 8. Surface Electrodes

For this arm we used surface electrodes. Electrode used to measure ECG, EEG and EMG potentials from the surface of the skin.

EMG Signal Processing: The difference of raw EMG signal as acquired by the electrodes is in the range of tens of micro volts. At the front end, we used a differential amplifier as a preamplifier stage, which amplified the signal by about 1000. The signal is analyzed in the frequency domain using FFT (Fast Fourier Transform) so that different discrete frequency components become known. This FFT consists of components of both signal and noise. To distinguish the signal from noise, we identified those frequency components which responded quickly and significantly due to contraction and relaxation of muscles. Experimentally, the change in amplitude was found to be maximum for components up to 40 Hz.

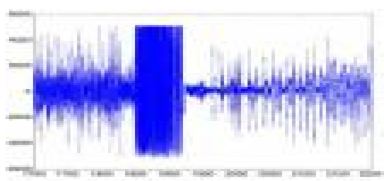

Fig. 9. Raw EMG Signal.

For these frequency components, a Low Pass Filter with a cut off frequency of 40 Hz was used**.** After filtering, the signal was boosted by an A.C. coupled amplifier of gain 1000 to compensate the attenuation caused by the filter. Power frequency noise of 50 Hz was minimized by Twin-T-Notch Filter. After further amplification, the signal was converted to D.C. To minimize patient-to-patient variation, a variable gain amplifier was used. The signal is then digitized and fed to the motor driver and control unit.

Artificial Arm: Artificial arm is needed to support the disable part of the body and circuitry.

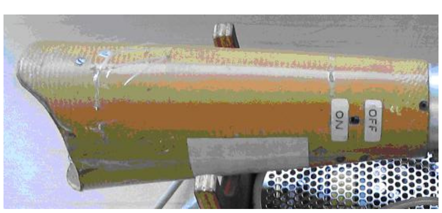

Fig. 10. Artificial Arm.

Microcontroller: Microcontroller is a general – purpose device that is meant to read data, perform limited calculation on that data, and controls its environment based on those calculation. The prime use of a microcontroller is to control the operation of a machine using a fixed program that is stored in ROM and that does not change over the lifetime of the system. The design approach of the microcontroller mirrors that is it makes much application as possible in order to sell, hopefully as many as possible.

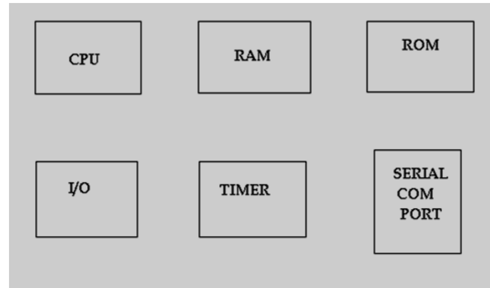

Fig. 11. Microcontroller System.

The microcontroller has a CPU in addition to fixed amount of ROM, RAM, I/O application in Ports, and Timers, are all embedded together on one chip this will make microcontroller idle for many which cost and space are critical.

Motor Driving and Control Unit:

The various building modules of the system are:

Touch Switches:

A pair of touch switches remains in contact with antagonistic wrist muscles flexors and extensors. The wrist flexors activate the 'CLOSE' switch while extensors operate the 'OPEN' touch switch. Thus touch switches pick up the signals from the skin surface. A minimum of 10-15μV myo-signals is needed for activating the corresponding switch.

Amplifiers: Each electrode signals is fed to one input of a differential amplifier. This enables us to select only the signal generated by the muscle for control of the terminal device, rejecting the common mode signal (noise interference) picked up by the electrode. When no electrode is activated, the amplifier remains in balance and no signal is transmitted to the terminal device. When any of the electrodes picks up a signal, the circuit is thrown out of balance and it operates the control relay.

Control Relay: A semiconductor relay working at 6V / 9V operates the motor. When the amplifier output is having one polarity, DC voltage is applied by the relay to the motor with certain polarity and motor rotates in one direction. When amplifier output changes its polarity due to the operation of second touch switch, the relay also changes the polarity of DC voltage being applied to the motor and consequently, motor rotates in opposite direction. Thus the hand closes and opens.

Micro switch: Two micro switches are provided in the hand to sense the extremities of hand in both directions - closing and opening. These micro switches cut the DC supply to the motor once the fingers reach the corresponding end point.

Filters: Since the myoelectric potential used for control are so small, there can be problem with outside interferences like 50 Hz electrical noise. There are many sources of noise which are strong enough to operate the prosthesis. These include radio signals, TV, static electricity etc apart from power line ripples. A filter removes all these noise signals.

System Specifications:

The specifications of above elbow prosthesis are as follows:

Operating Voltage	:	6V / 9 V
Current Consumption	:	800 mA (Approx.)
Opening Width	:	75-100 mm
Average Speed	:	3-4 cm/sec. (approx.)
Weight of arm	:	1.7 - 2 kg (max.)
On-off switch	:	Integrated
Wrist Rotation	:	Passive with ratchet lock
Elbow angular movement:		120° (max.)
Grip Force (proportional)	:	0-90 N

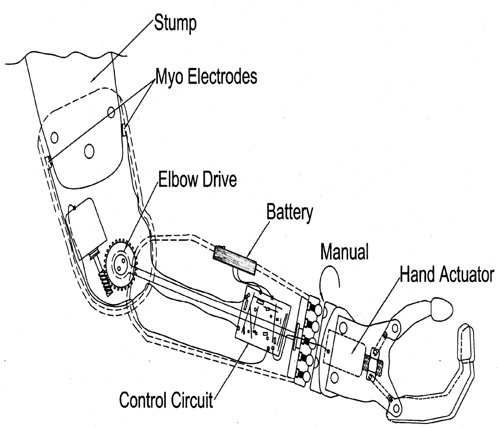

Fig. 12. Mechanical Layout of Arm.

The filtered signals from both myo-electrodes are fed to a differential amplifier which takes care of common mode noise. The output of this amplifier contains two useful information. Polarity of the output indicates which myo electrode has been operated by the patient and Magnitude of the output indicates the amount of grip force the patient wants to exerts on the object to be grasped. The output of amplifier is passed through an integrator whose output is, in turn, fed to a sample and hold circuit. This DC voltage is used to flow a proportional armature current in the motor to produce a proportional torque.

EMG Amplifier and Band Pass Filter Circuit Design:

The amplifier circuit is divided into two stages consisting of

- Amplification stage.
- Band pass filter stage

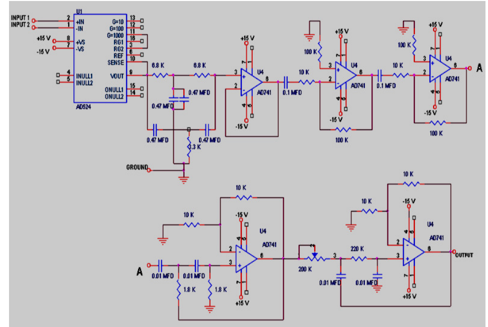

Fig. 13. Circuit Design for EMG Amplifier and BP Filter.

VI. CONCLUSION

The fabricated arm is good enough for opening and closing of hand according to the muscle activity and therefore it can lift the object and place it at different place comfortably. A load of up to 2 kg can be lifted by the developed hand. However, the arm does not have the intelligence to adjust itself according to the requirement of grip force i.e. it cannot differentiate between the objects of different weights. In real life, the objects are of different weights and textures and gripping force to be exerted on the object must vary accordingly (e.g. a thermocol glass must not be crushed due to the gripping by hand). So designed myoelectric arm which applies grip force on the object according to its weight. This is possible without any feedback circuit because the physical understanding of the object is done by our brain. The muscle signal amplitude generated in response to the brain directive is ultimately to be translated into the proportional armature current of the motor to generate a proportional torque (and thus the proportional grip force) exerted by our hand.

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