PPU College of Engineering and Technology

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COLLEGE OF ENGINEERING AND TECHNOLOGY

Electrical Engineering Department

Industrial Automation Engineering Program

GRADUATION PROJECT REPORT

EXO SKELETON FOR PERIPHERAL PARALYSIS CONTROLLED BY EMG SIGNALS

Project Team

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ABSTRACT

Spinal cord injurie and other local injuries often lead to peripheral paralysis, while the brain stays fully functional. When this peripheral paralysis occurs in the hand, these individual are not able to execute daily activities on their own even if their arms are functional.

To remedy this problem, design an exoskeleton needs to assist paralyzed individuals. The exoskeleton's movements are controlled by the user's available electromyography(EMG) signals, a new control technique will developments to allow for a natural reaching and facilitator sequence by the natural residual muscle activation patterns.

But the signal need to purity and enlarge before entering to microcontroller, then run the motor to controlling exoskeleton.

الملخص

اصابات الحبل الشوكي وإصابات محلية أخرى غالبا ما تؤدي إلى الشلل الطرفي، في حين أن الدماغ تبقى تعمل بكامل طاقتها. عندما يحدث هذا الشلل الطرفي في اليد، فإن تلك اليد تصبح غير قادرة على تنفيذ الأنشطة اليومية من تلقاء نفسها حتى لو كانت الأذرع موجوده.

لمعالجة هذه المشكلة, تم تصميم بيت خارجي يتم توظيفه لمساعدة المشلولين طرفيا, حيث ان حركات اليد المتمثلة في حركة البيت الخارجي يتم التحكم بها من خلال إشارة كهربائية العضلة (EMG signals), تقنية التحكم الجديدة سوف يتم بناؤها و تطويرها لتسمح بوصول الاشارات بشكل طبيعي و تسلسل ميسر باستخدام أجزاء العضلات الطبيعية الفعالة المتبقية .

ولكن الإشارة تحتاج الى تنقيه و تكبير قبل الدخول الى المتحكم الدقيق ، ومن ثم تشغيل المحركات التي تقوم بالتحكم في البيت الخارجي لليد.

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Abbreviation Table

Description	Abbreviations
Electromyography	EMG
International Society of Electrophysiological Kinesiology	ISEK
Peripheral Nervous System	PNS
Central Nervous System	CNS
Biceps Muscle	BI
Triceps Muscle	TRI
Fast Oxidative Glycol tic	FOG
Fast Glycol tic	FG
Motor Unit Action Potential	MUAP
Chlorine Ions	Cl-
Silver Ions	Ag+
Common Mode Rejection Ratio	CMRR
Lower Frequency	FL
Higher Frequency	FH
Low Pass Filter	LPF
High Pass Filter	HPF
Digital to Analog Converter	DAC
Variable Reluctance	VR
Permanent Magnet	PM
Hybrid	HB
from Renesas ElectronicsMicrocontroller Family	RX
from Tenesas ElectronicsMicrocontroller Family	TX
Printed Circuit Board	PCB

1 Chapter One

General Background

1.1 Introduction

Not a small Percentage of people out of our Palestinian society have a weakness in one of limbs that happened by some congenital reasons or kind of accidents or was done on the hand Israeli occupation in what it does against our Palestinian nation, and out of this case it is a part of our duty in order to help them doing their daily actions normally, and now we will go to the mechanization of doing this project.

Electromyography is a technique for evaluating and recording the electrical activity produced by skeletal muscles. EMG is performed using an instrument called an electromyography, to produce a record called an electromyography.

An electromyography detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, and recruitment order or to analyze the biomechanics of human or animal movement.

EMG signals are not easily observed as they are weak signals in range of 1-100mV,so an EMG signal needs to be amplified by an amplifier specifically designed to measure it in order to be observed. The EMG signal is picked up by electrodes and then amplified. Generally more than one amplification stages as necessary in order to eliminate the low and high frequency noises or the other factors that can affect the output data.

EMG signal accuracy is dependent on many parameters such as electrodes number electrode placement, electrode orientation, electrode type, inter-electrode distance, skin preparation, skin and electrode gel temperature, subcutaneous fat between the electrode and muscle. The EMG signal is used for much application such as control computers and other devices.

In our project the EMG signals are tried to use for controlling of a simple hand-shaped gripper with a microcontroller interface, as shown in figure (1.1).

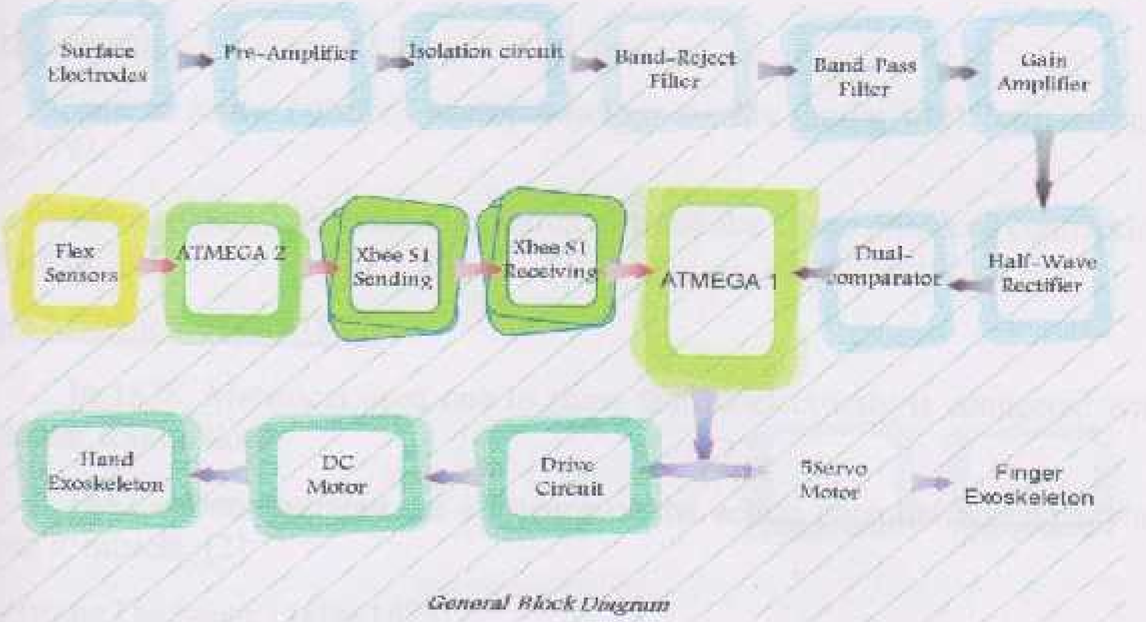

Figure (1.1):- The General Block Diagram.

1.2 Project Aim

The proposed project aims at design an artificial hand (limb) by using and processing muscle signals...

1.3 Literature Review

Francesco Redi (1626-1698)

First to recognize connection between muscles and generation of electric 1666—documented that electric ray fish used a highly-specialized muscle. [1]

Alessandro Volta (1745-1827)

Developed a device which produced electricity,which could be used to stimulate muscles, invented the first electric battery. [1]

Luigi Galvani

Credited as the father of neurophysiology for his similar work with frogs' legs-1791.

Showed that "electrical stimulation of muscular tissue produces contraction and force. [1]

Carlo Matteucci (1820-1845)

In 1838, Matteucci used one to show that bioelectricity is connected with muscular contraction.

1842 – Demonstrated the existence of the action potential accompanying a frog's muscle. [2]

Guillaume Duchenne (1806-1875)

1850 – Applied electric stimulation to intact skeletal muscles Interested in medical electricity for therapeutic purposes. Systematically mapped out functions of nearly every facial muscle Knowledge of EMG developed as fast as technology could keep up. [2]

The term electromyography comes from Etienne Marey, who modified Lippman's capillary electrometer (1876) as one of his many contributions to kinesiology. [2]

John Bas 1962

Basmajian compiles all of the known information about EMG. Also created fine - wire electrodes that were more comfortable than needles and could be used longer. The book Muscles Alive becomes an invaluable tool in the field and is updated through five editions, the last Carlo De Luca. Founded International Society of Electrophysiological Kinesiology, ISEK, in 1965.ISEK worked to create standards for EMG usage and reportingmajian. [2]

1.4 Project Main Component

1) Detecting Electrode.
2) Amplifier.
3) Microcontroller.
4) Stepper motor and driving modules.
5) Hand-shaped gripper.

1.5 Estimated Project Cost

Table (1.1): Component Cost:

No.	Description	Price/ NIS
1	Electrodes and Fillters	200
2	Amplifiers	100
3	4N25 opt-coupler	5
4	LM319D Dual-Comparator	10
5	AD620 Amplifier	140
6	Resistors + Capacitors + Rectifiers	60
7	2 Arduino + shield	400
9	Darlington Transistors	50
10	5 servo motors	1100
11	5 Flex Sensors	500
12	2 Xbee module S1+ shield	500 + 100
13	DC Motor for hand + Drive Circuit	400
14	2 Gears	150
15	design lathing (Exoskeleton)	1500
16	Hand – shaped Gripper (polyethylene)	1400
17	Other materials	300
18	Paint	400
	Total	7315

1.6 Time Diagram

Table (1.1): Time line1 of The Project:

Weeks Tasks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Literature review and problem statement															
Proposing methodology															
Components survey and cost estimation , selec.															
Reporting Project chapters															
Design of system part															
Report Typing															
Report submission															

Table (1.3): Time line 2 of The Project:

Weeks / Tasks	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Starting implementation of the mechanical design	■	■	■	■	■	■									
Purchasing the components			■	■	■	■	■	■	■						
Assembly the electrical and mechanical part							■	■	■	■					
Testing and calibration										■	■	■			
Typing the final report													■	■	
Report submission and preparing the project presentation															■

2 Chapter Two

Structure Background

2.1 Anatomy of the Human Forearm

Initially, we talk about the Peripheral Nervous System (PNS), which is the other part of the nervous system. The main task of the PNS is to detect stimuli and send impulses to the CNS according to the stimuli. The PNS is made of receptors and nerves that carry the impulses. Receptor cells are ones whose function is to detect something about its environment.

There are many receptors in the body that are able to detect many changes like temperature, touch, light, sound and chemicals. There are some organs in the body that are there to detect just one stimulus, like the eye for example. These are called sensory organs and they can be defined as a group of receptor cells responding to specific stimuli.

Effectors are the opposite of receptors. Receptors are two detect the stimuli while effectors are two respond to it. Effectors are usually muscles and glands.

2.1.1 Neuroses (Nerve Cells)

Neuroses are one of the most important structures of the nervous systems. Neuroses act as a wire that transmits electrical impulses all over the body. Like a cable that consists of many wires, a bundle of neuroses is called a nerve. There are 3 types of neuroses; each type is to transmit electrical impulses from a specific place to another.

1) Motor Neuroses :-

This is a neurosis that transmits electrical impulses from the Central nervous system to the effectors, as shown in figure (2.1).

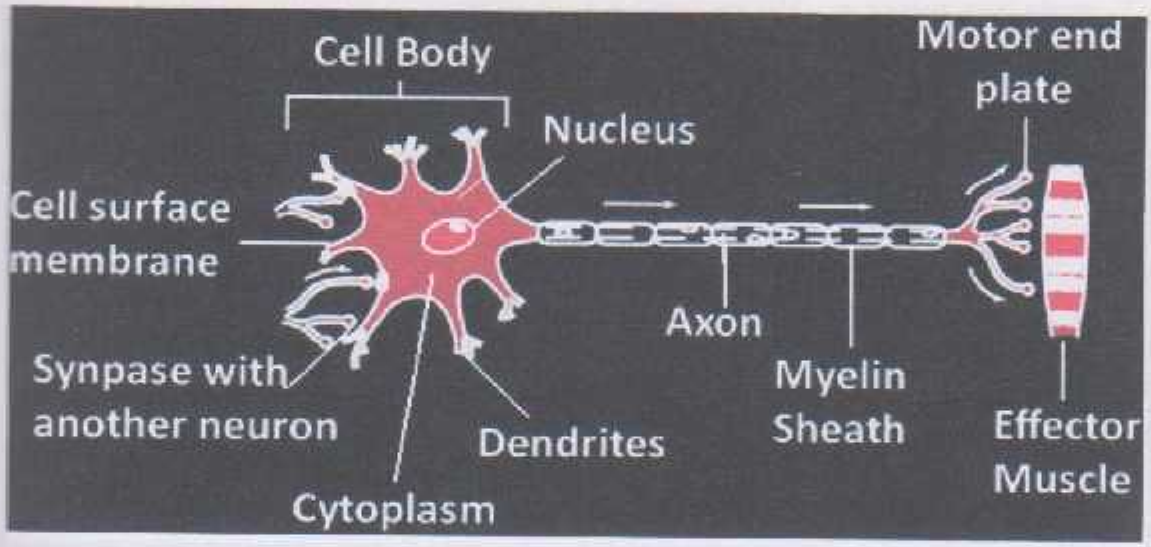

Figure (2.1):- Structure of Motor Neuroses. [4]

The Neuron is made up of three segments; the cell body which is the start of the motor Neuron and is in the CNS, axon which stretches out from the cell body all the way to end of the neuron, and the motor plate which is the end of the Neuron and is in the Effectors muscle.

Neurons have features that are common between most animal cells like a nucleus, cymiddlelasm and cell surface membrane, but they also have some exclusive features like the axon. The axon is an extended cymiddlelasm thread along which electrical impulses travel. Some motor neurons have axons of length 1 meter. Axons are coated by a layer of myelin called myelin sheath; this is an electrically insulating layer which is essential for the proper functioning of the nervous system.

Another exclusive feature of neurons is dendrites; these are several short threads of cymiddlelasm coming out of the cell body. Their function is to pick up electrical impulses from other cells.

The last exclusive feature of motor neurons only is motor end plate. This is just the end of the axon which is in the muscle. It passes the electrical impulses from the neuron to the muscle fibers.

2) Sensory Neuroses :-

Like other neurons, sensory neurons carry electrical impulses from one place to another. But sensory neurons carry electrical impulses in the direction different to that of motor neurons, from the receptors to the CNS, as shown in figure (2.2).

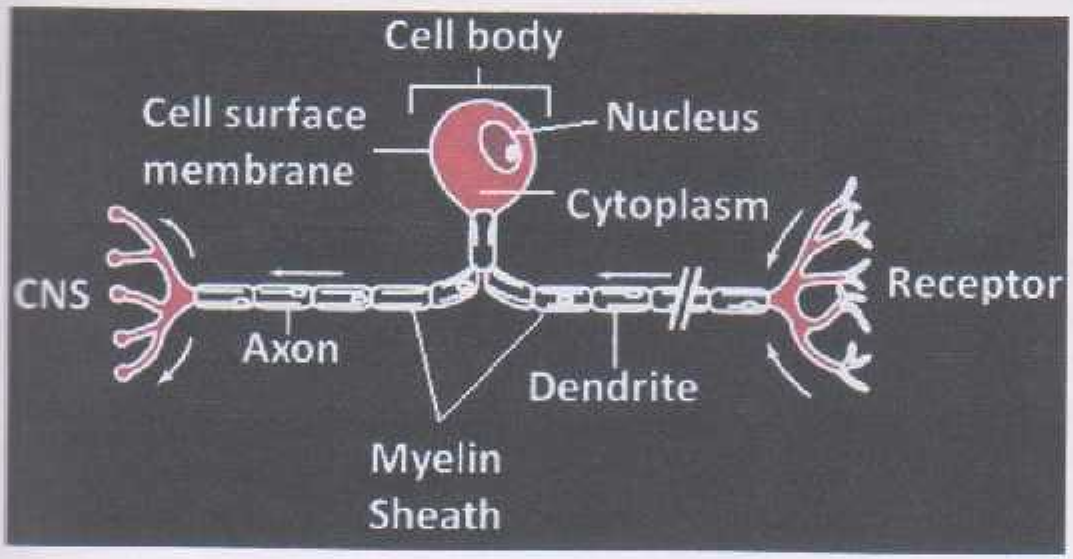

Figure (2.2):- Structure of Sensory Neuroses. [4]

3) Relay Neurons :-

Relay neurons are located in the CNS. Their job is to pass electrical impulses from the sensory neuron onto the motor neuron, so it acts like a diversion, as shown in figure (2.3).

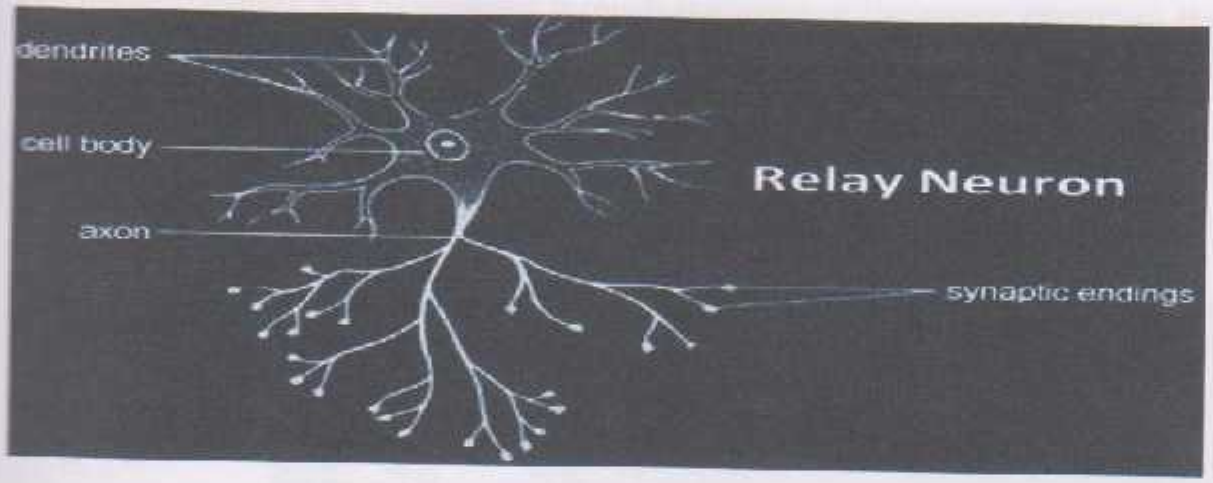

Figure (2.3):- Structure of Relay Neuroses. [4]

2.1.2 Reflex Arc (Nervous System in Action)

Where neurons meet, they are not actually touching each other. Instead there is a gap called synapse or junction box. When the electrical impulses reach the end of a neuron, the neuron secretes a chemical transmitter which passes by diffusion to the other neuron causing the impulses to be carried from the first neuron to the second.

If your finger touches a hot surface, receptor cells in the skin of your finger detect a stimulus, which is a sudden rise in the temperature. The receptor uses the energy of the stimulus to generate electrical impulses. These impulses are then carried by the axons of the dendrites of the sensory neuron through cell body to axon and from the axon to the CNS. At the CNS the electrical impulses travel through the synapse to the relay neuron, which passes it onto the motor neuron. The nerve impulses are transmitted through the axon of the motor neuron to the targeted muscle which contracts when electrical impulses reach it, resulting in your finger being pulled away from the hot surface, as shown in figure (2.4).

This pathway is called the reflex arc and happens in about a fraction of a second.

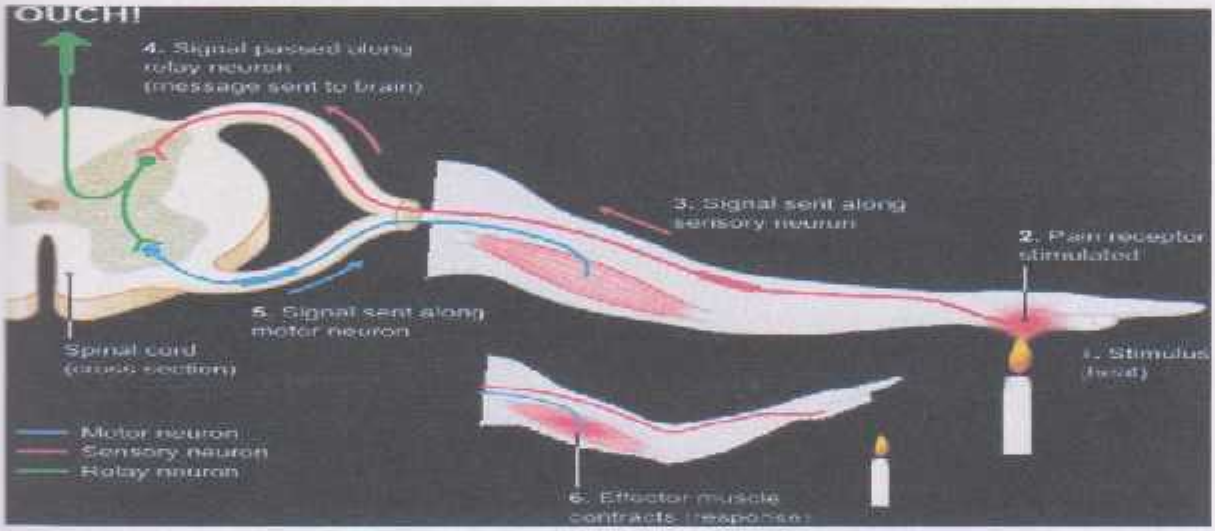

Figure (2.4):- Reflex Arc: Receptor → Sensory Neuron → CNS → Motor Neuron → Effectors. [5]

2.1.3 Antagonistic Muscles

We have just learned that in order for the pupil to get narrower or wider, two muscles work simultaneously, when one contracts the other relaxes. Pairs of muscles like that are called antagonistic muscles.

The most known antagonistic muscle pair is the biceps and triceps of the arm. The bi and the tri for short; they are what cause the movement of the arm. They work simultaneously to bend or straighten the arm. The biceps is located in front of the humerus bone of the upper arm. The biceps is joined to the radius bone of the lower arm and the triceps is joined to the ulna bone of the lower arm. Muscles are attached to bones by strong fibers called tendons.

And to learn how to deliver the pulse of the muscle, we will address the case of bend and straighten muscle:

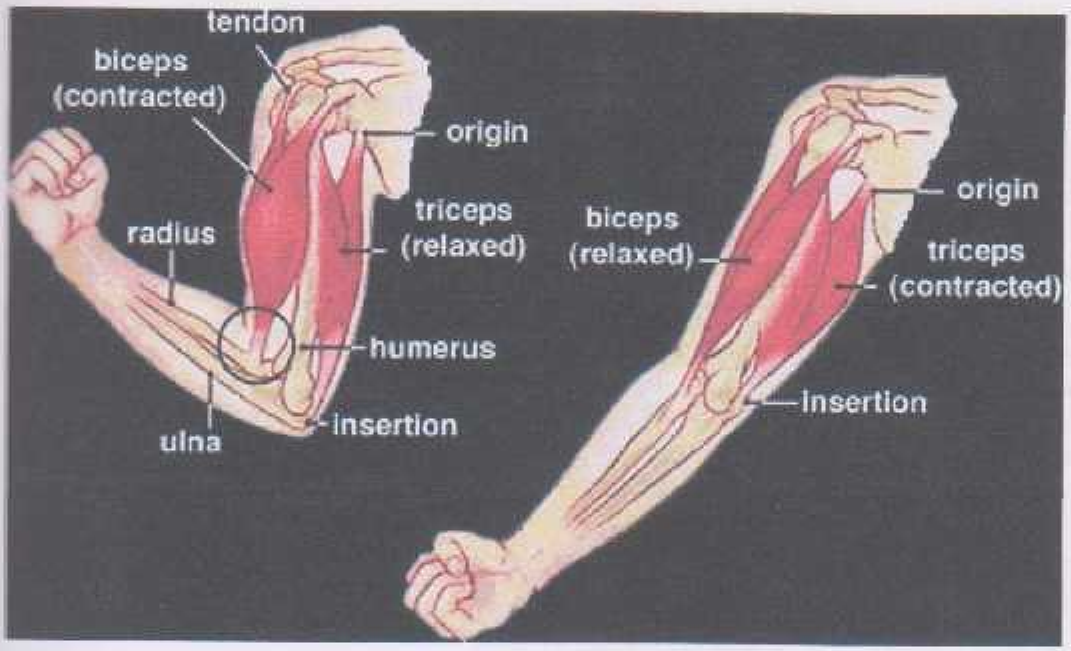

Figure (2.5):- The Effect of Bend and Straighten Arm. [6]

When you want to bend your Arm the brain send two electrical impulses, one to the bi making it contract and one to the tri telling it to relax.

To straighten your arm, the brain send electrical impulses to both muscles making the bi relax in order to leave the muscle it is attached to free. The tri contracts and becomes shorter pulling the muscle it is attached to into place and straightening the arm.

As shown in figure (2.5); the biceps can be called a flexor because it flexes (bends) the arm. the triceps can be called an extensor because it extends (straightens) the arm. It is necessary to explain the affected part of the man who will be replaced by another part mechanic to make up the shortfall effectively.

This section will be covered in detail the muscles involved with each finger movement, as shown in figure (2.6).

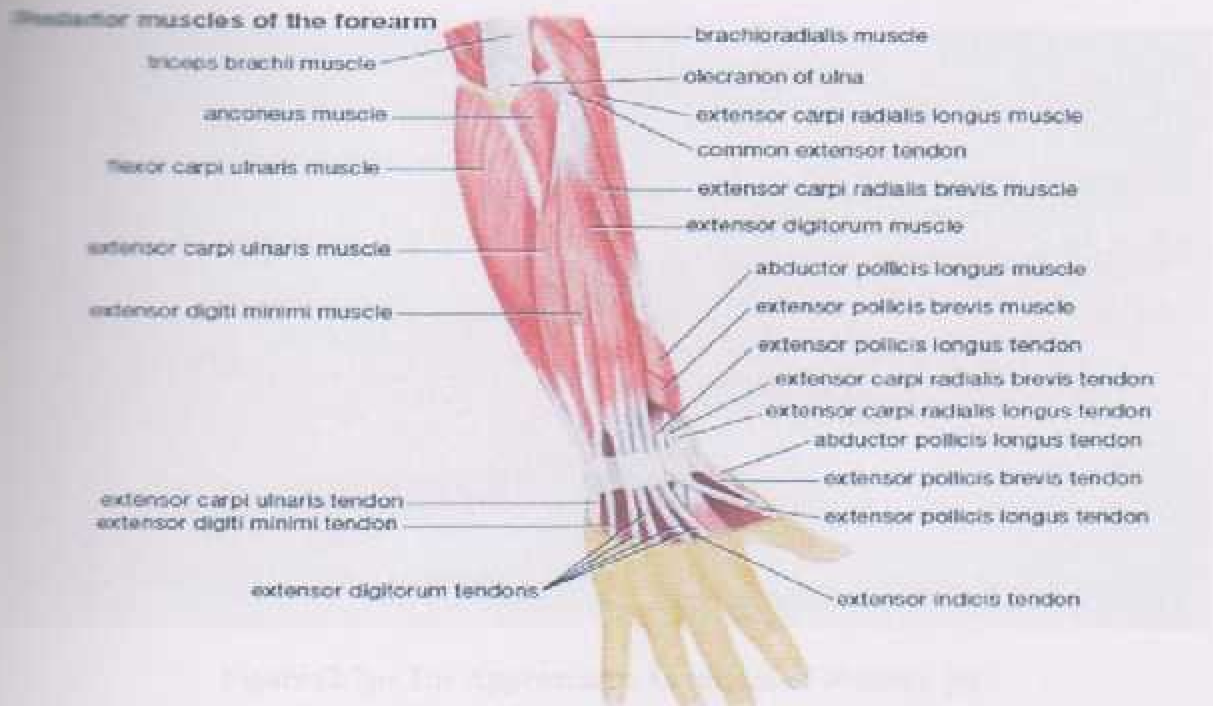

Figure (2.6):- Structural of Human Arm. [7]

The muscles of interest for determining grasp classification are the extensor muscles, generally located on the posterior side of the forearm. The extensor muscles extend the fingers outward as the grasp initially takes form. It is the proper capture and classification of the EMG signal during this initial movement that enables a real-time classifier to work. The specific extensor muscles involved are the extensor digitorum, extensor pollicis longus, extensor pollicis brevis, extensor indicis, and extensor digiti minimi. The extensor digitorum is responsible for the extension of the finger joints and wrist, and connects primarily to the middle and ring fingers, and secondarily to the index and little fingers. The extensor pollicis longus and extensor pollicis brevis are both responsible for the extension of the thumb as well as abduction at the wrist. The extensor indicis muscle controls both the extension and adduction of the joints of the index finger, while the extensor digiti minimi controls the extension of the joints of the little finger.

The approximate locations of these muscles are indicated, as shown in figure (2.7).

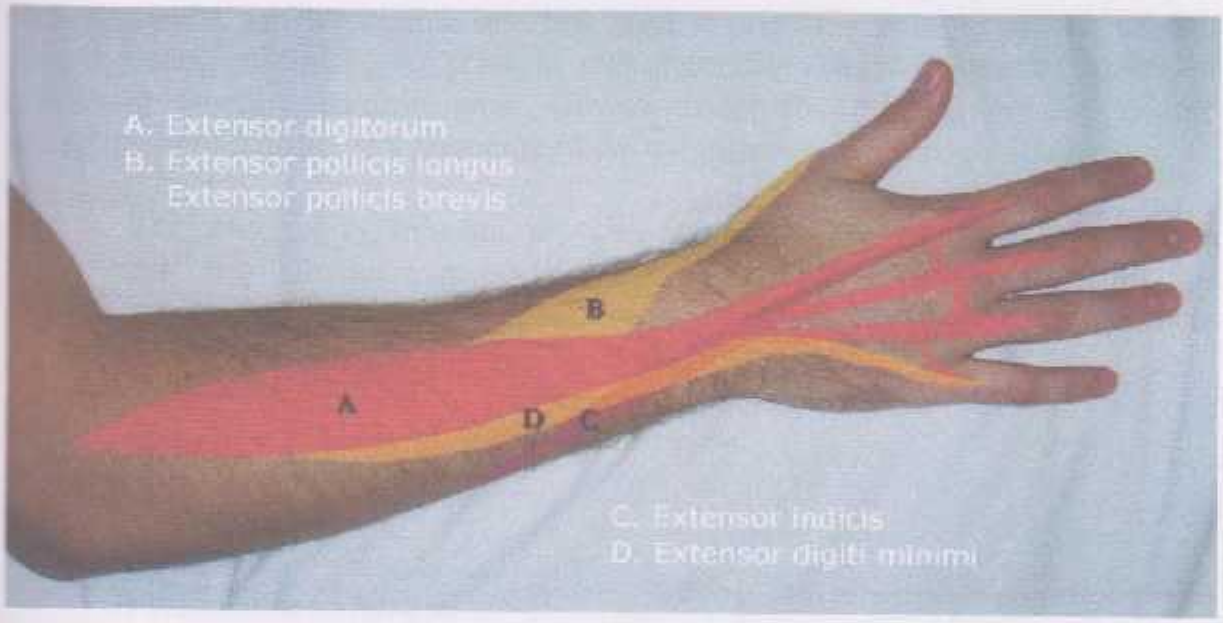

Figure (2.7):- The Approximate Locations of Muscles. [8]

The extensor indicis muscles are actually in the muscle layer below the extensor digiti minimi and extensor digitorum. Naturally, the deeper location of this muscle will have a negative impact on the energy that surface electromyography can detect.

The flexor muscles, generally located on the anterior side of the forearm, are responsible for flexion of the finger joints. For continued grasp control, following the initial classification, the flexor muscles should be monitored with additional electrodes. Ideally, the EMG collected from these muscles would indicate the closing of a grasp, the continued maintenance of a grasp, and the degree of tension used to maintain the grasp, as shown in figure (2.7).

2.2 Muscle Fibers

Muscle Fibers are formed during development from the fusion of several undifferentiated immature cells known as myoblasts into long, cylindrical, multi-nucleated cells. Differentiation into this state is primarily completed before birth with the cells continuing to grow in size thereafter. Skeletal muscle exhibits a distinctive banding pattern when viewed under the microscope due to the arrangement of cytoskeletal elements in the cytoplasm of the muscle fibers.

The principal cytoplasmic proteins are myosin and actin (also known as "thick" and "thin" filaments, respectively) which are arranged in a repeating unit called a sarcomere. The interaction of myosin and actin is responsible for muscle contraction.

- **Functional Properties of muscle fibers :-**

  1) Peak Force.
  2) Contraction velocity.
  3) Resistance to fatigue.
  4) Actino-myosin ATPase activities.

Four main types are commonly identified, although further sub- group are known. For our purposes, we will focus on the four major types described here:-

1) Fast-twitch fibers - used in Anaerobic Exercise:

(Short, high energy exercise)

a) Two types of Fast - twitch fibers (A and B).
b) Fast-twitch fibers are more glycol tic than Slow-twitch fibers.
c) More explosive.
d) Exercises such as weightlifting and sprinting.

2) Fast- twitches fibers:

a) Fast oxidative glycolytic (FOG)- these fibers have plenty of energy and oxygen.
b) Fast and fatigue resistant (maintain force production after many contractions).

3) Fast-twitch B fibers:

a) Fast glycolytic (FG)- these fibers have a low oxygen capacity making it hard to complete multiple contractions without rest.
b) Fast and fatigable (high force production but fatigued after only a few contractions).
c) Low oxidative capacity.

4) Slow-twitch fibers- used in Aerobic Exercise (long, constant energy):

a) Red=slow oxidative.
b) More oxidative.
c) Mitochondria (cells power source, gets energy out of glucose in respiration) are bigger and there are more of them.
d) More capillarieo More myoglobin (a protein with oxygen bound to it so that there is an oxygenreserve for long periods of exercise) .
e) Long twitch times, low peak forces, high fatigue resistance.
f) Exercises such as long distance running and bike riding.

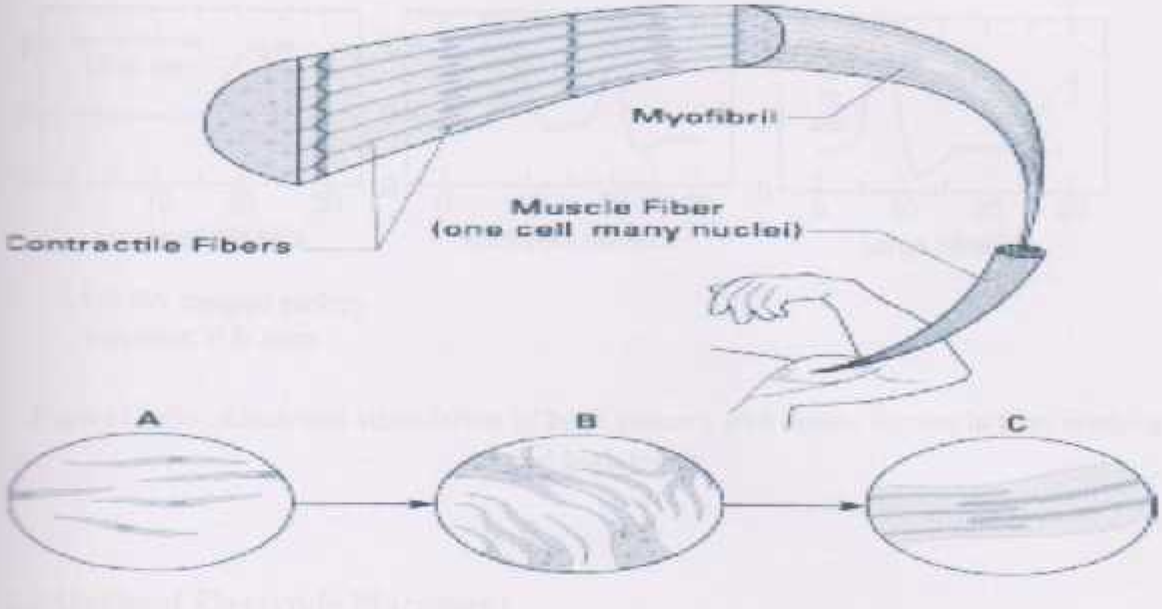

Figure (2.8):- Skeletal Muscles Move by Contracting. [9]

Each muscle is composed of tightly packed bundles of muscle Fibers, each containing proteins, which are responsible for muscle movement. Differentiation of muscle cells begins early in embryonic development. Myoblasts (A), the precursors of skeletal muscle cells, fuse together (B), to form multinucleated cells which eventually develop into myofibrils containing contractile fibers (C), as shown in figure(2.8).

After explain that previously, in our project will be the sensory neuron is inoperative, so we will compensated it by take the electrical signal from the motor neuron by using "Electrical stimulation of both sensory and motor nerves", it is used to record the reflex response of the muscle, however by:

1) At low stimulating levels some of sensitive sensory nerves are activated, but the motor nerves are not and hence **M** response is not seen. Also AP of the sensory nerves moves to spinal cord and generate reflex response.
2) For moderate stimuli both motor nerves and sensory nerves are stimulated and two responses are seen (**M** and **H**).
3) For large stimuli only **M** response is seen, as shown in figure (2.9).

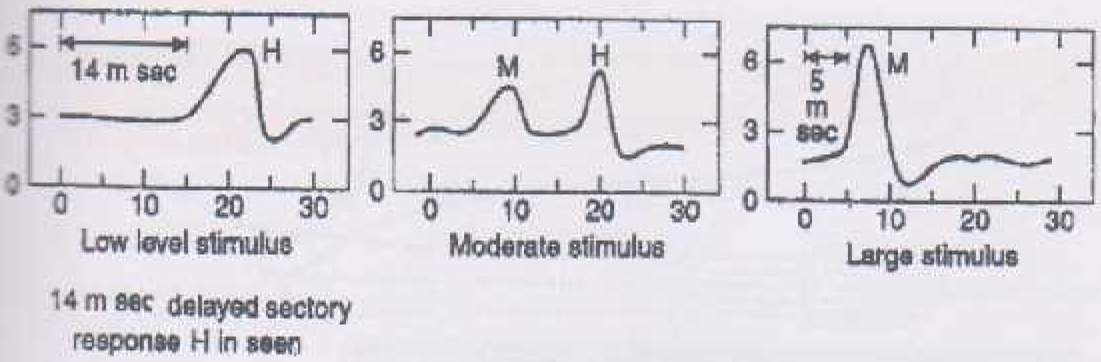

Figure (2.9):- Electrical stimulation of both sensory and motor nerves in low, moderate and high levels.

2.3 Optimal Electrode Placement

There are several factors that must be considered and addressed in order to ensure effective EMG signal detection. To receive maximum results from your stimulation, it is important to place the electrodes correctly. Electrodes from the same pair should be placed over the same muscle (surface electrodes must be placed parallel to the muscle fibers).

The optimum placement varies slightly from person to person, so we try moving the electrodes around until you get the most comfortable and effective contractions. There are many company offers different sizes of electrodes. Small electrodes are preferably used on smaller muscles and large electrodes on larger muscles. Before placing the electrodes on your body, be sure to always wash and dry the skin in order to ensure good conductivity. be sure to only place electrodes on healthy skin. And we should never place electrodes closer than 3 cm from each other.

The figure (2.10) shown muscle stimulation, the electrodes placed over or nearby the painful area.

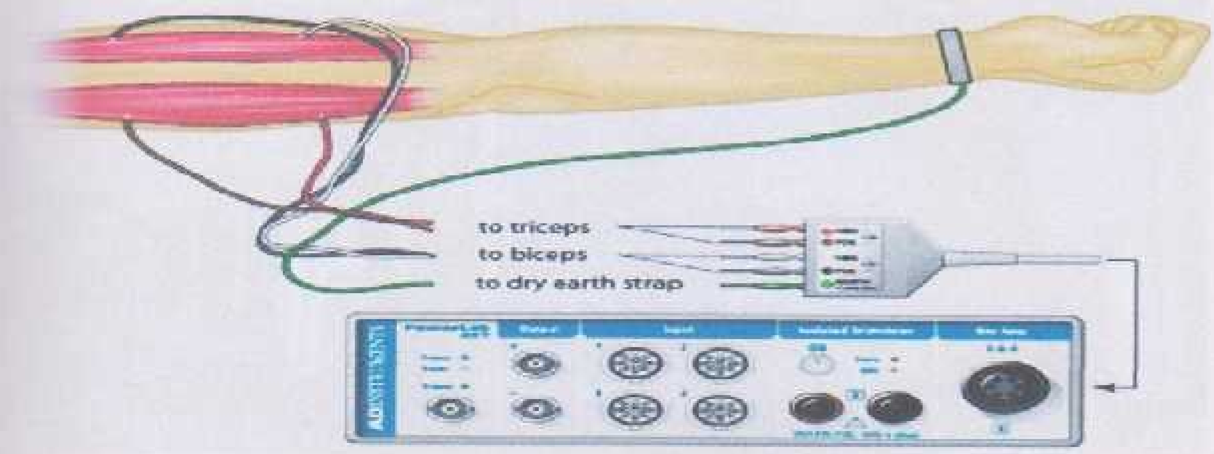

Figure (2.10):- Muscle Simulation. [10]

2.4 Skin Preparation and Electrode Placement

In order to minimize the impedance between the electrode-skin contacts, recommends that the skin surface be shaved of any hair and dead skin cells at the target location. Dry shaving works well for removing the dead skin cells. Once shaved, the skin should be cleaned with alcohol and allowed to dry before the electrodes are placed, as shown in figure (2.11).

Then, to ensure that the electrode is in the correct location, first secure the body reference electrode to the subject's wrist, on the anterior side. Then, using Siriprayoonsak's EMG Capture Program or the Establish Grasp Power procedure in the Real-Time EMG Classifier, test various positions around the target muscle area while performing a hand extension action with the corresponding muscle. The goal is to find the location that produces the greatest energy (highest amplitude) during activity and the least energy (noise) while in a rest position.

Figure (2.11):- Correct Location Test. [11]

2.5 Normalizing the Electrodes

The voltage potential of the EMG signal detected by the electrodes strongly depends on several factors, varying between individuals and also over time within an individual.

Thus, the amplitude of the EMG itself is not useful in group comparisons, or to follow events over a long period of time. The fact that the recorded EMG amplitude is never absolute is mainly due to the fact that the impedance varies between the active muscle fibers and electrodes and is unknown therefore, when comparing amplitude variables between measurements, normalization of some kind is required, and i.e. the EMG converted to a scale that is common to all measurement occasions.

Normalizing the signal amplitude with respect to force or torque is a commonly used technique. Typically, the EMG is related to a maximal contraction, or a sub maximal contraction at a known level of force.

3

Chapter Three

System Components

3.1 Hand System

3.1.1 EMG System

3.1.1.1 The Nature of EMG Signal

Our muscles cause our body parts to move through contraction and relaxation. Each muscle consists of many muscle fibers, which range in length from a few millimeters (mm) to about 30 centimeters and have a diameter of between 10 and 100 micrometers. The muscle fibers will shorten to about 57% of their resting length during contraction. All of the muscle fibers making up a particular muscle do not contract simultaneously; rather, small groups of muscle fibers contract and relax together, as directed by their motor unit. The motor unit is the fundamental building block of an EMG signal. It consists of a motor neuron, its axon, and all of the muscle fibers that it controls. Countless motor units provide the pathway from the central nervous system to muscle fibers. However, individual motor units vary by size and by the number of muscle fibers that they innervate, from a few to over a thousand. Additionally, the innervated muscle fibers of multiple motor units are randomly intermingled (see Figure 3.1), meaning that a portion of a muscle may contain fibers belonging to between 20 and 50 different motor units.

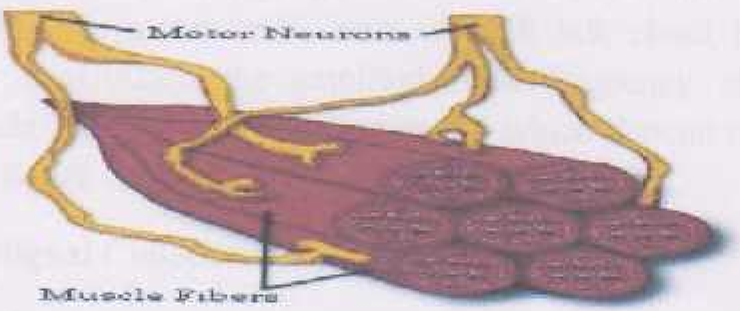

Figure (3.1): Depiction of Two Motor Units Controlling Intermingled Muscle Fibers.[12]

Just prior to muscle contraction and the application of force, an increasing number of motor units are recruited for muscle activation. The motor units are typically recruited according to their size, beginning with the smaller motor units first. The exchange of ions across the muscle fibers innervated by the recruited motor units results in small electrical currents, which combined for a particular motor unit is referred to as the motor unit action potential (MUAP) .The aggregate electric signal generated from all of the MUAPs in a detected area is referred to as the myoelectric signal, a recording of which is called an electromyogram (EMG). Note that this signal propagation precedes muscle.

Motion with about 10 to 100 mS. This 100 mS lead helps to minimize the length of the EMG signal is used to the hand grip , which is essential for the success of a real-time classifier and prosthetic hand control skeletal muscles contributes to the weight of the body , the skeleton classify muscle can rotating directly fastened by means of a joint, and the striated muscle to a bone or by means of tendon . Two or more groups of the skeletal muscles working against each other (s) extends . The skeletal muscle is composed of poly - nucleus cells. Action potential propagates from motor nerve to the muscle fibers controlled by the nerves, will cause and start after molecular mechanism. An immediate increase of calcium ions into the muscle cell reproduction After Identifying the nature of the EMG signal and their relationship with the motor unit , now we will talk about the EMG signal collection for Determined the amplitude and frequency of the discharge electrical muscle , and identify the factors All which depend on the quality of the EMG signal.

3.1.1.2 EMG Signal Collections

The basic component of skeletal muscle is the motor unit, which can be activated consciously. A number of the motor units construct a so-called muscle fiber (as explained previous in the second chapter). When a single motor unit (SMU) is activated by stimulation, a potential waveform with amplitude of 20-2000 μV, a discharge frequency of 6-30Hz, and an interval of 3-10 mS is observed. Thus, contraction of muscle fibers leads to a potential signal with larger amplitude and higher frequency.

It is electromyogram (EMG) as explained previous in chapter two. The motor unit regulates the fiber of skeletal muscle. Therefore, when a motor nerve is excited, the fibers controlled by this motor unit will all be activated. This process includes the production of action potential and contraction of muscle fibers. A single piece of muscle may be probably by hundreds of motor units. The nervous system makes an attempt to control different degrees of muscle activities by means of

Stimulating diverse numbers of motors units. More the motor units are excited; more the muscle fibers are activated.

The quality of an EMG signal is subject to several factors, including:

1) Timing and intensity of muscle contraction.
2) Distance of the electrode from the target muscle area.
3) Properties of the tissue overlying the muscle, skin thickness, and fatty tissue.
4) Properties of the electrodes and the amplifier.
5) Quality of the contact between the skin and electrode, including stability.

The first factors, timing and intensity of muscle contraction, encompass the data that we want to quantify and classify for each of the muscles involved in making a particular hand grasp. It is the changes in these factors that make distinguishing hand grasps using an EMG signal possible.

Naturally, the distance between the electrode and the target muscle area impact the quality of the EMG signal. Understanding the human anatomy and proper electrode placement, covered in sections 2.1 and 2.3, respectively, will help to minimize this distance.

There are several properties of the muscle and surrounding tissue that affect the EMG signal. The muscles are surrounded by extracellular fluid, fatty tissue, and skin, which cause inflections in the current field and varying levels of impedance.

Skin tissue has greater impedance than muscle tissue and therefore acts as a filter for the signal. With increasing tissue between the electrode and the target muscle, the amplitude of the EMG signals drops precipitously. Subjects with thicker skin or greater body-fat percentage will have more of the signal filtered before reaching the electrode, making proper electrode placement significantly more critical for those individuals. Muscle tissue impedance is directionally dependent, which also affects electrode placement.

Some studies have shown 7 to 10 times greater impedance levels in measurements taken perpendicular to the muscle fibers versus measurements taken in the parallel direction. The muscle tissue can also be affected by biochemical changes, which impact the conduction velocity of the muscle fibers and filtering properties of the muscle tissue. Biochemical changes occur over multiple sessions and even during the same session, to some degree. Ensuring a large training set and maintaining consistent electrode placement should mitigate some of these challenges. The properties of electrodes and amplifiers affecting the quality of the signal are addressed in detail in the next two subsections, while the quality of the electrode to skin contact is addressed in section.

After identifying that, will go to talk about electrodes, the identification of any kind of electrode kinds and the electrodes suitable location.

3.1.1.3 Surface Electrodes

Human body consists of numerous liquid cells which contain different electrolyte ions. The intracellular liquid includes ions of potassium, sodium and chloride. Action potential comes from the variations of ion concentration. When an electrode is used to detect action potential, the so-called interface potential will be generated. Imagine, when a metal electrode touch certain electrolyte solution, two kinds of chemical reactions will simultaneously occur. One is oxidation reaction in which metal atoms will release electrons and become metal ions.

The order is reduction reaction in which electrons and metal ions will be combined together and become metal atoms. In the interface between metal and electrolyte liquid, the ions with positive and negative charges will move in an opposite direction and produce two ions layers with opposite electricity. The potential difference between two ion layers is called interface potential. Immersing different between metals into electrolyte liquids will lead to different levels of interface potential.

Thus, for measuring biological signals, it is necessary to choose a metal with low interface potential as an electrode material. This can avoid the excessive interface potential during measurement. In general, the biological signal range is from 50μV-1mV and the interface potential of metal is in the range of 0.1-1V. Additionally, the interface potentials of electrodes vary with time.

There are two types of electrodes used in the recording of the EMG signals; surface electrodes and needle electrodes.

While needle electrodes are inserted through the skin into the muscle tissue, surface electrodes are placed on the surface of the skin. In this project, surface electrodes (Ag/AgCl) are used as they are easy to use and can be applied without pain. Surface electrodes come in many varieties mostly characterized by number of contacts, as figure (3.2). Nowadays silver-silver chloride (Ag/AgCl) is the most used material for the production of electrodes. This kind of electrode is principally made by silver. There is a thin layer of AgCl formed by the contact between silver and electrolyte solution. And AgCl provides silver (Ag^{+}) and chlorine (Cl^{-}) ions a bi-directional exchange.

The detected amplitude normally ranges up to 5 mV for surface electrodes and up to 10 mV when using needle electrodes .The cut-off frequency of the surface electrodes vary from 10 to 1000 Hz. As the signals obtained are too low, noise is a big problem and it must be considered in the design of the system.

The motion artifact in the electrode skin interface is one of the reasons of noise caused the electrodes, which has frequencies 0-10Hz. The use of high-pass filtering, shielded cables, carefully taping to reduce cable movement and mounting the amplifier near the electrodes can minimize this effect.

The electrode placement and location has a big importance in the EMG recording, surface electrodes must be placed parallel to the muscle fibers. The skin must be cleaned and electrode conducting jell must be used for better results. Reference electrodes must be used near the bony parts.

Figure (3.2): Surface Electrodes. [13]

3.1.1.4 Noise and Artifacts

EMG recording can be interference by noise from different sources, not only by the noise from the bioelectric generator or active cell but also from the electrical fields that occur around lead cables and electrode. Electrical fields such as power lines, computer monitors, transformers, or even EMG amplifier itself might cause noise that wills interference the signal. Because of the electronic components acting as antennas, recording devices, ambient noises, motion artifacts the design of the amplifier should have been designed considering the noise factors.

Ambient noise can be generated from any electric device that creates electromagnetic field. The ambient noise cannot be avoided, it occurs primarily between the 50-60Hz band.

Two of the important parameters in bioelectric amplifiers are noise and drift. Drift is the change in output signal voltage due to changes in operating temperature and noise, in this case, is the thermal noise generated in resistances and semiconductor devices. Instrumentation amplifier is used in the pre-amplification stage of the project to perform the crucial differential signal combination and it is the solution to both high-gain and high-input impedance prop-lems. Instrumentation amplifier consists of three operational amplifiers; two non-inverting followers as input amplifiers followed by a differential amplifier. [14]

3.1.1.5 EMG Implementation

At the end of this section we want to get out with the implementation full of the EMG system so that it has the surface electrodes (explained previously), pre-amplifier, isolation circuit, band-reject filter, band-pass filter, gain amplifier, half-wave rectifier, integrator and buffer circuit.

3.1.1.5. 1 Pre-Amplifier

This pre-amplifier uses a two non-inverting amplifier and a typical differential amplifier circuit, which contains two inputs (positive input and negative input). The differential amplifier circuit subtracts two inputs and amplifiers the difference, as shown in Figure (3.3).

To get the right level of the input signal, we need a body reference circuit which works as a feedback from the inputs. Whenever the body temperature changes or signal changes due to noise introduced by the body, this body reference will help maintain the correct level of signal. In each input channel, there is one body reference feedback.

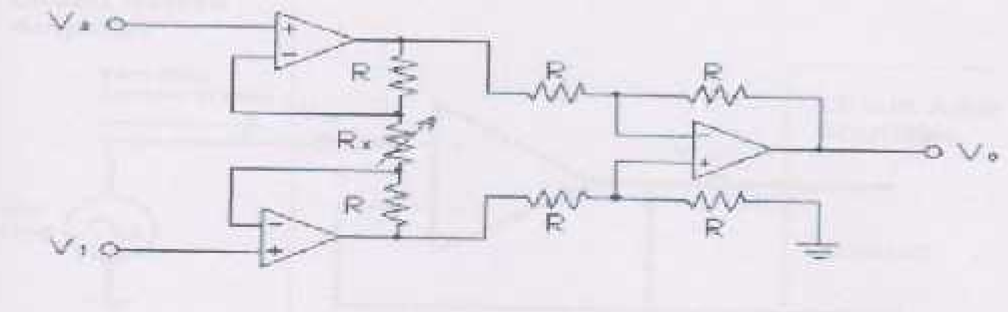

Figure (3.3):- Pre-Amplifier Circuit.

We will replace this circuit by electronic piece called AD620, because it Easy to use, low noise, high CMRR, and high Z $_{in}$, and high accuracy that requires only external resistor to set the gain of circuit, as shown in Figure (3.4).

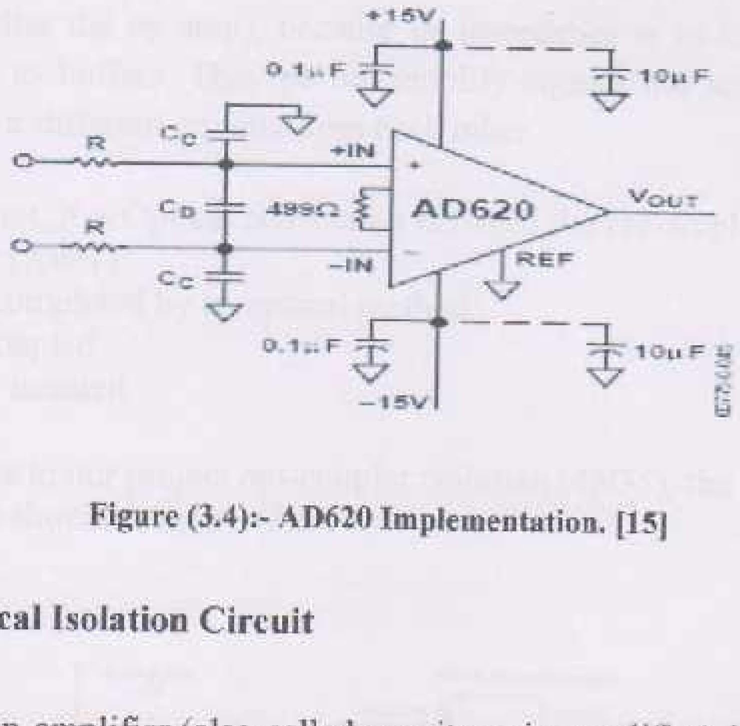

Figure (3.4):- AD620 Implementation. [15]

3.1.1.5.2 Optical Isolation Circuit

An isolation amplifier (also called a unity-gain amplifier) is an op-amp circuit which provides isolation of one part of a circuit from another, so that power is not used, drawn, or wasted in a part of the circuit the purpose of isolation amplifier isn't to amplify the signal. The same signal that is input into the op amp gets passed out exactly the same. This means that output voltage is the same exact as the input voltage.

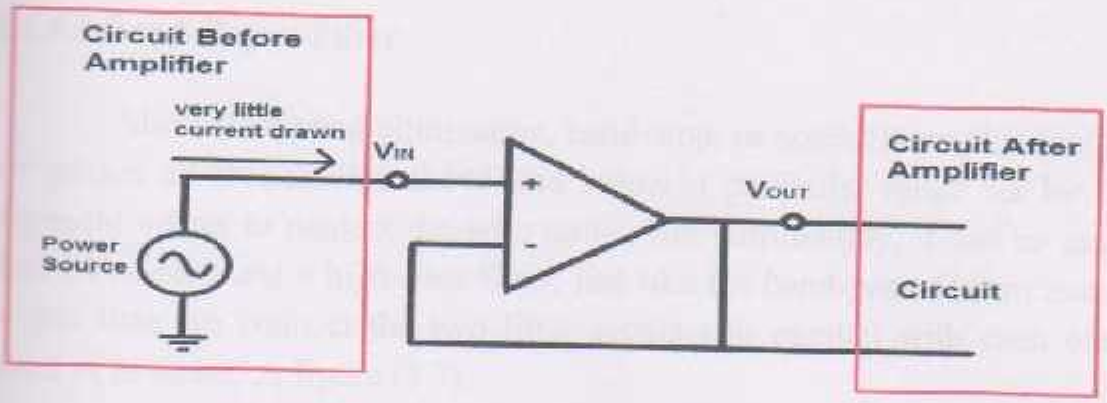

Figure (3.5):- Isolation Amplifier Circuit.

Figure (5.3) illustrates a little current from the power source above. Because the op amp has such high impedance, it draws very little current. The first part of the circuit, then, is undisturbed, and, thus, is isolated from the second part of the circuit. The op amp serves as an isolation device so that practically no current gets drawn and transferred to the second part of the circuit (circuit after the op amp), because its impedance is so high. Isolation amplifiers serve as buffers. They do not amplify signals but serve to isolate parts of circuits or different circuits from each other.

In our circuit, it is Optical connection between the pre-amplifier and the band-reject filter (Av=1).
The isolation is completed by an optical method:

- Optically coupled.
- Electrically isolated.

We will use in our project opt-coupler isolation (4N35), the functional block diagram as shown in figure (3.6).

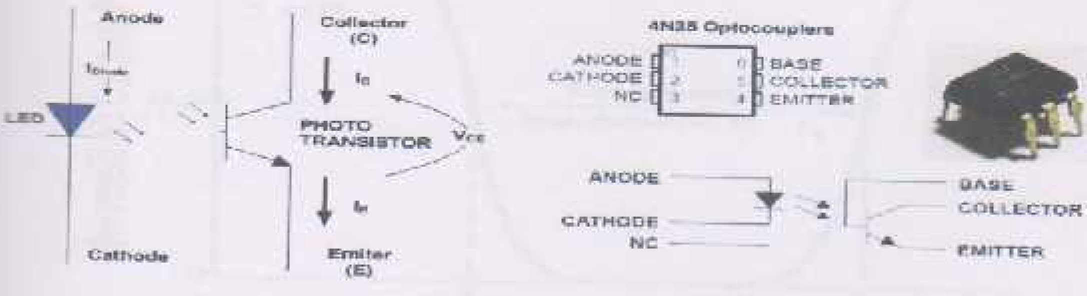

Figure (3.6):- Functional Block Diagram of The Opt-Coupler (4N35). [16]

3.2.1.5.3 Band-Reject Filter

Also called band-elimination, band-stop, or notch filters, this kind of filter passes all frequencies above and below a particular range set by the component values to neglect the wire noise. Not surprisingly, it can be made out of a low-pass and a high-pass filter, just like the band-pass design, except that this time we connect the two filter sections in parallel with each other instead of in series, as figure (3.7).

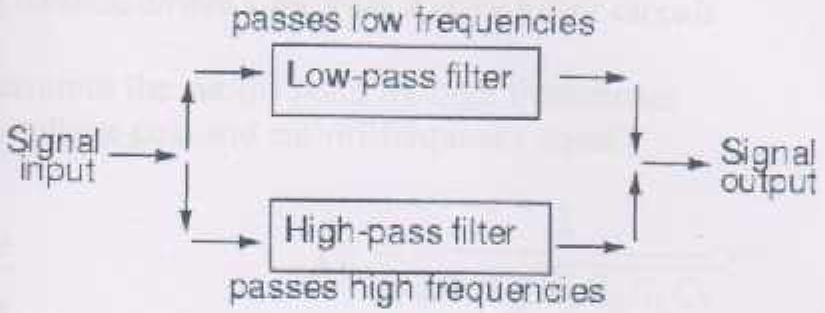

Figure (3.7):- System Level Block Diagram of a Band-Reject Filter.

Band rejection filters are used when relatively wide band of frequencies need to be rejected, is the opposite of a band-pass filter, as in figure (3.8).

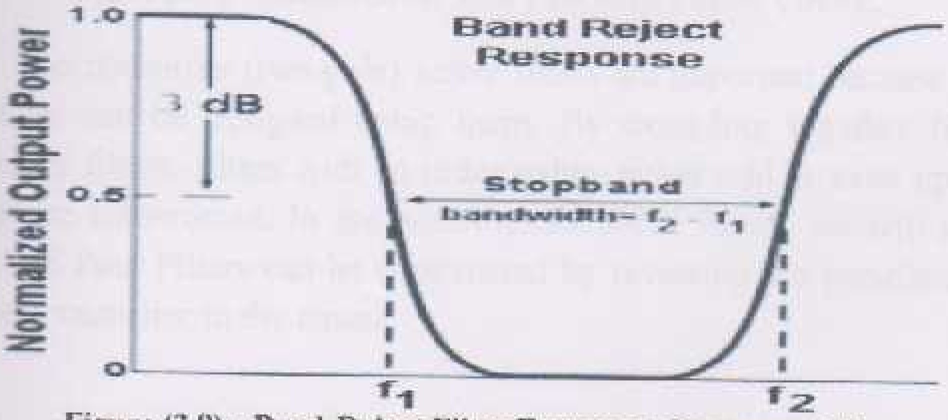

Figure (3.8):- Band-Reject Filter Frequency Response. [17]

3.1.1.5.4 Band-Pass Filter

Used in electronic systems to separate a signal at one particular frequency or a range of signals that lie within a certain "band" of frequencies from signals at all other frequencies. This band or range of frequencies is set between two cut-off or corner frequency points labeled the "lower frequency" (fL) and the "higher frequency" (fH) while attenuating any signals outside of these two points.

3.1.1.5.4.1 Second-order Low Pass Active Filter circuit

- Determines the cut-off point for high frequencies.
- The voltage gain and cut-off frequency equal:

$$A_v = 1 + \frac{R_2}{R_1} \qquad F_C = \frac{1}{2\pi * \sqrt{R_3 R_4 C_1 C_2}}$$

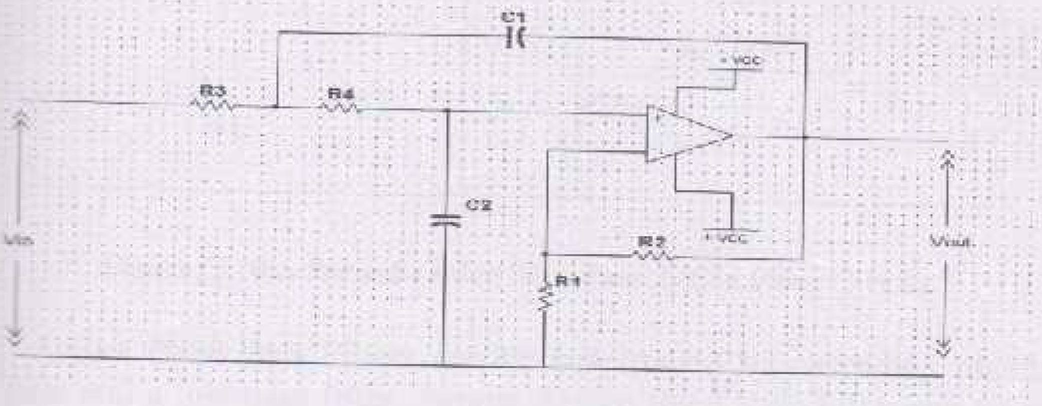

Figure (3.9):- Second-Order Low Pass Active Filter Circuit.

Second-order (two-pole) active filters are important because higher-order filters can be designed using them. By cascading together first and second-order filters, filters with an order value, either odd or even up to any value can be constructed. In the next tutorial about filters, we will see that Active High Pass Filters can be constructed by reversing the positions of the resistor and capacitor in the circuit.

3.1.5.4.2 Second-order High Pass Active Filter Circuit

Determines the cut-off point for high frequencies

The voltage gain equal: $A_V = 1 + \frac{R_2}{R_1}$

Cut-off frequency equal :

$$F_C = \frac{1}{2\pi * \sqrt{R_3 R_4 C_1 C_2}}$$

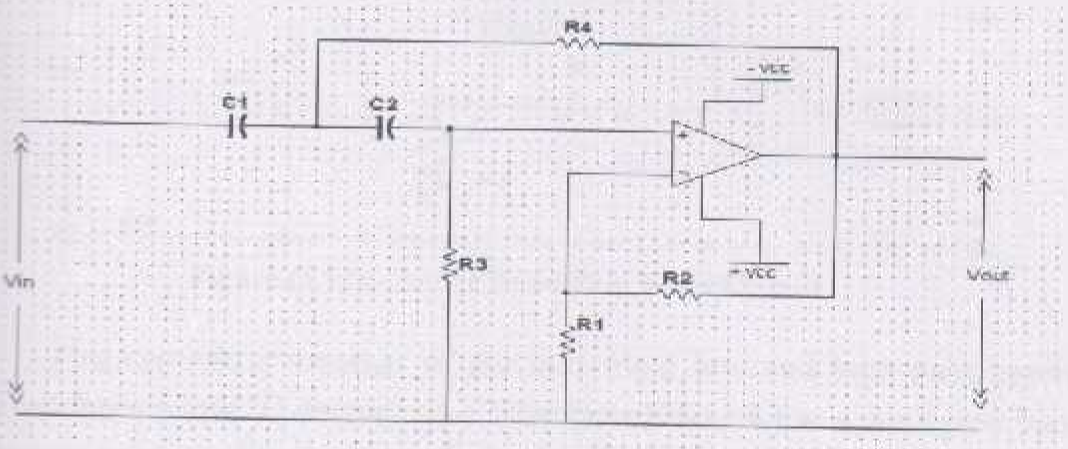

Figure (3.10):- Second-Order High Pass Active Filter Circuit.

Active Band Pass Filters can be constructed by cascading together a high pass and a low pass filter. Simple Active Band Pass Filter can be easily made by cascading together a single Low Pass Filter with a single High Pass Filter as shown in figure (3.11).

Figure (3.11):- Active Band Pass Filters Construction.

The cut-off or corner frequency of the low pass filter (LPF) is higher than the cut-off frequency of the high pass filter (HPF) and the difference between the frequencies at the -3dB point will determine the "bandwidth" of the band pass filter while attenuating any signals outside of these points. One way of making a very simple Active Band Pass Filter is to connect the basic passive high and low pass filters we look at previously to an amplifying op-amp circuit as shown in figure (3.12).

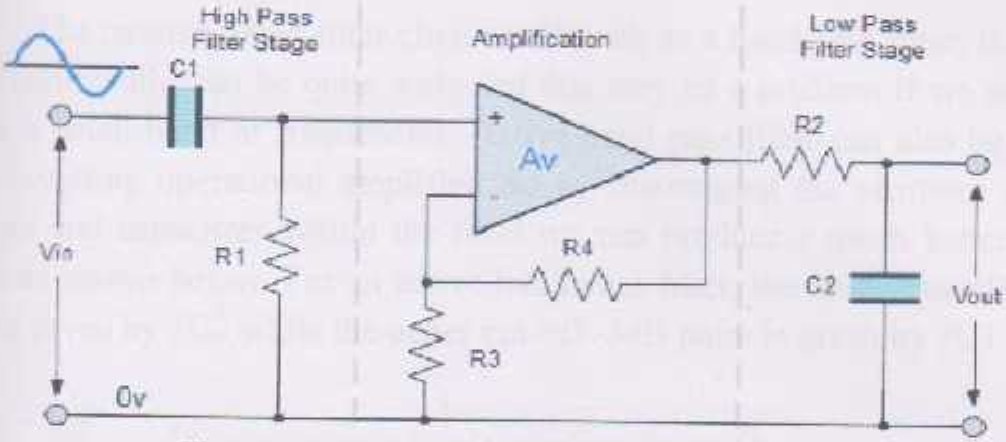

Figure (3.12):- Active Band Pass Filter Circuit.

This cascading together of the individual low and high pass passive filters produces a low "Q-factor" type filter circuit which has a wide pass band. The first stage of the filter will be the high pass stage that uses the capacitor to block any DC biasing from the source. This design has the advantage of producing a relatively flat asymmetrical pass band frequency response with one half representing the low pass response and the other half representing high pass response as shown in figure(3.13).

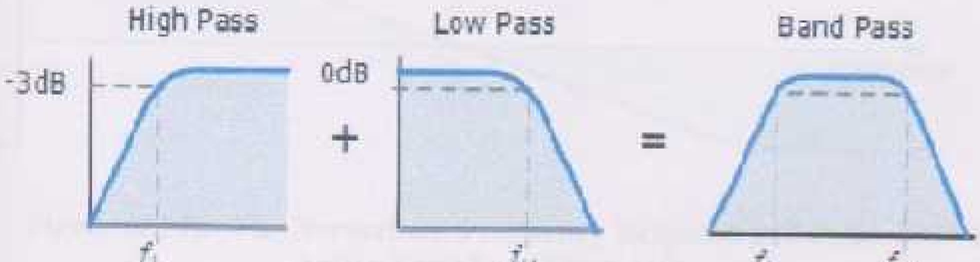

Figure (3.13):- Band-Pass Filter Response.

The amplifier also provides isolation between the two stages and defines the overall voltage gain of the circuit. The bandwidth of the filter is therefore the difference between these upper and lower -3dB Points. The normalized frequency response and phase shift for an active band pass filter will be as shown in Figure (3.14).

- Active Band Pass Frequency Response:

The passive tuned filter circuit will work as a band pass filter, the pass band (bandwidth) can be quite wide and this may be a problem if we want to isolate a small band of frequencies. Active band pass filter can also be made using inverting operational amplifier. So by rearranging the positions of the resistors and capacitors within the filter we can produce a much better filter circuit as shown below. For an active band pass filter, the lower cut-off -3dB point is given by $fC2$ while the upper cut-off -3dB point is given by $fC1$.

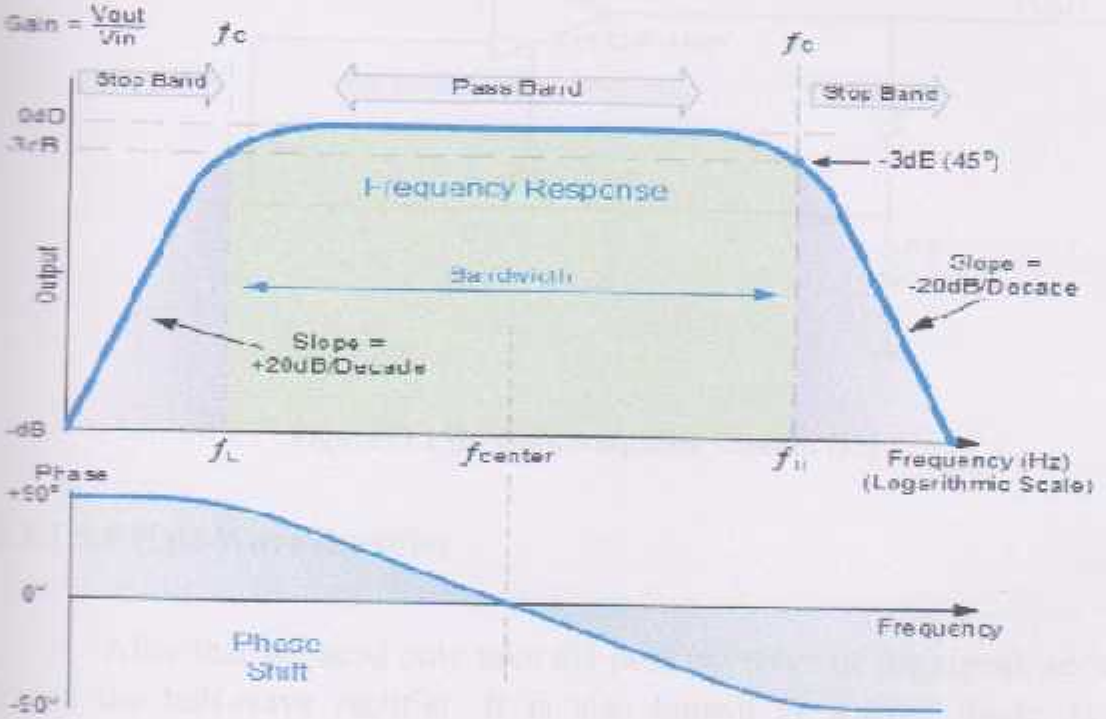

Figure (3.14):- The Normalized Frequency Response and Phase Shift for an Active Band Pass Filter. [18]

3.1.1.5.5 Gain Amplifier

Gain amplifier is as a non-inverting amplifier, such that; the output voltage changes in the same direction as the input voltage. that the non-inverting input of the operational amplifier will need a path for DC to ground; if the signal source might not give this, or if that source requires a given load impedance, the circuit will require another resistor — from input to ground. In either case, the ideal value for the feedback resistors (to give minimum offset voltage) will be such that the two resistances in parallel roughly equal the resistance to ground at the non-inverting input pin, as in figure (3.15). we will use the gain amplifier, because through change a gain of it. We get the output needed.

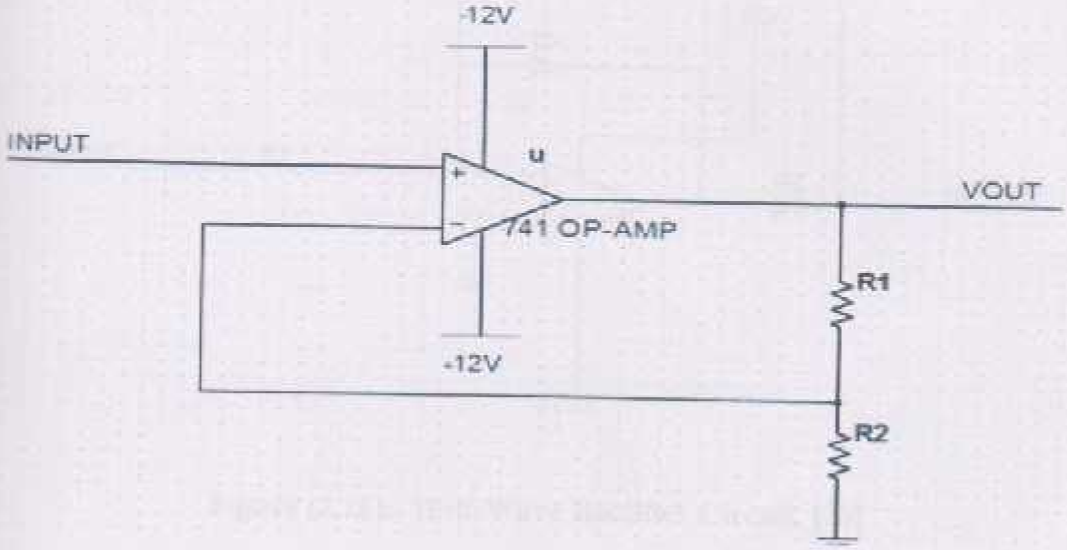

Figure (3.15):- Gain Amplifier Circuit. [19]

3.1.1.5.6 Half-Wave Rectifier

After that we need only take the positive wave of the signal, so we will use the half-wave rectifier. It is also known as a super diode, is a configuration obtained with an operational amplifier in order to have a circuit behave like an ideal diode and rectifier. it is useful for high-precision signal processing.

When the input is positive, it is amplified by the operational amplifier which switches the diode on. Current flows through the load and, because of the feedback, the output voltage is equal to the input voltage.

When the input is greater than zero, D1 is OFF and D2 is ON, so the output is zero because one side of R_2 is connected to the virtual ground, and there is no current through it. When the input is less than zero, D1 is ON and D2 is OFF, and the output is like the input with an amplification of $-R_2/R_1$. This circuit has the benefit that the op-amp never goes into saturation, as shown in figure (3.16).

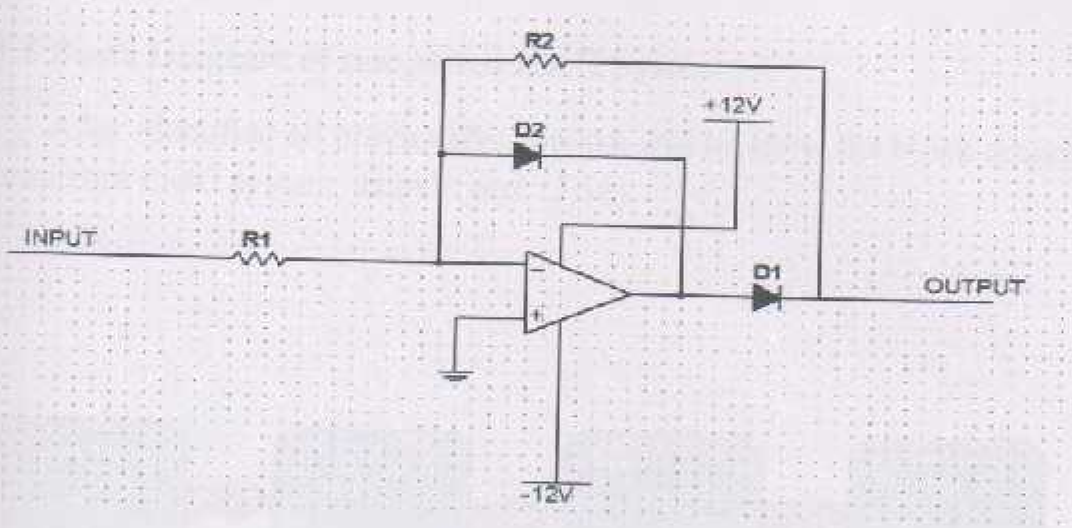

Figure (3.16):- Half-Wave Rectifier Circuit. [20]

3.1.1.5.7 Dual-Comparator

After that we will have two signals, one coming from a biceps muscle and other from a triceps muscle, enter each one to the different comparator by using dual-comparator, such that, When reach the signal from the biceps muscle, go out signal from the first comparator to move the motor, but when reach a signal from the triceps muscle, go out signal from the second comparator to reverse the motor rotation. In other word (how move the hand, moves the motor). We will use in our project (LM319D) dual comparator, The LM319 is a dual high speed voltage comparator designed to operate from a single +5V supply up to ±15V dual supplies, as shown in figure (3.17).

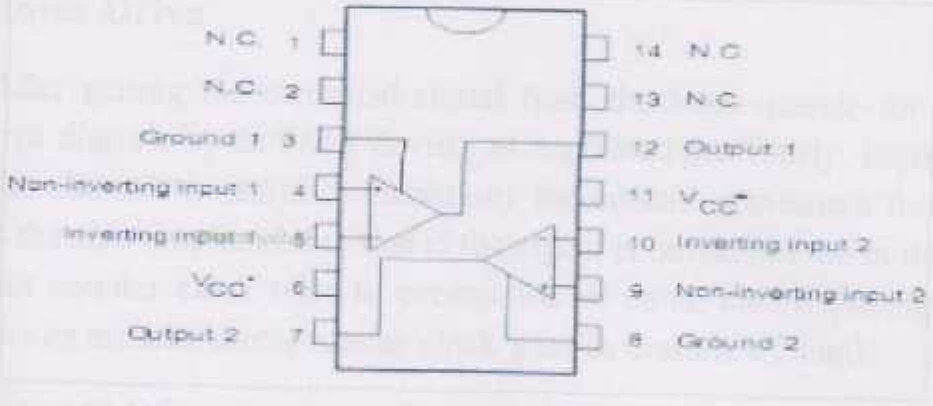

Figure (3.17):- LM319D (Dual-Comparator) Implementation. [21]

3.1.1.6 Block Diagram of completed EMG System

After identified all previously, now we will be show the block diagram of completed EMG system, as in Figure (3.18).

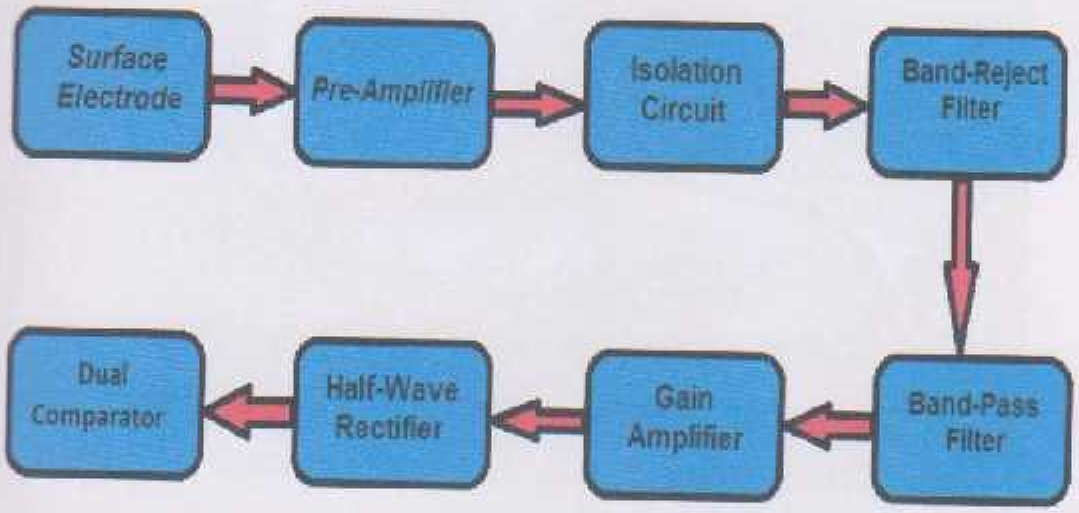

Figure (3.18):- Block Diagram of The Completed EMG System.

3.1.2 Motor Drive

After getting the electrical signal from the hand muscle for either contraction or diastole by an EMG device, as explained previously, introduced this signal to the microcontroller (Arduino) for control movement motor is installed on the side arm hand. So, that if the signal is outside of the bi muscle; motor rotates counter clock wise to contraction of hand, else if the signal is outside of the tri muscle, motor rotates clock wise to diastole of hand.

We used DC motor type of power window LH as shown in figure (3.19), Where we will design it in order to get moves 90 degrees and this movement is very suitable for the movement of the hand, it also has high torque approximately 30 kg.cm, speed of about 85 RPM, size of acceptable and needs to be fed by a 12 V.

Figure (3.19):- Power Window Motor LH.[22]

3.2 Fingers System

In previous chapters, we have able to move the infected hand using the EMG signal that taken from the bi and tri muscles by a surface electrodes, But in order to take fingers signals from the muscles is so difficult and need to use a needle electrodes, and that need to surgery under the supervision of a doctor, and this is not available, to avoid this problem, we find a solution, which is take the fingers signals from the other right hand.

And we did it by installed a five flex sensors on the all fingers of the other right hand, when move this fingers will result from this sensors five signals, enter to the microcontroller to processing this signals as character and through serial pin in arduino. And to avoid contact wires in the hands of the patient and provide freedom of movement for him, we will use a wireless transfer data xbee module using a zigbee's technique . then uploading a code from first arduino to sending Xbee module, Which will be sending this code to receiving Xbee module installed on the infected hand through wireless characteristic, connect this Xbee module with other arduino to enter this code to it . And therefore, this code will move the servo motor as required. Now will recall all the pieces used full characteristics and principles operation each and explain why we used in detail.

3.2.1 Flex Sensor

Flex sensor are sensors that change in resistance depending on the amount of bend on the sensor , they convert the change in bend to electrical resistance – the more the bend , the more the resistance value .

The working principle as follows : the flex sensor are analog resistors they work as variable analog voltage dividers , inside the flex sensor are carbon resistive elements within a thin flexible substrate. More carbon means less resistance when the substrate is bent the sensor produces a resistance output relative to the bend radius . as shown in figure (3.20)

Figure (3.20):- Flex Sensors.[23]

The impedance buffer in the Basic Flex Sensor Circuit is a single sided Operational Amplifier, used with these sensors because the low bias current of the Op-Amp reduces error due to source impedance of the flex sensor as voltage divider, as shown in figure (3.21).

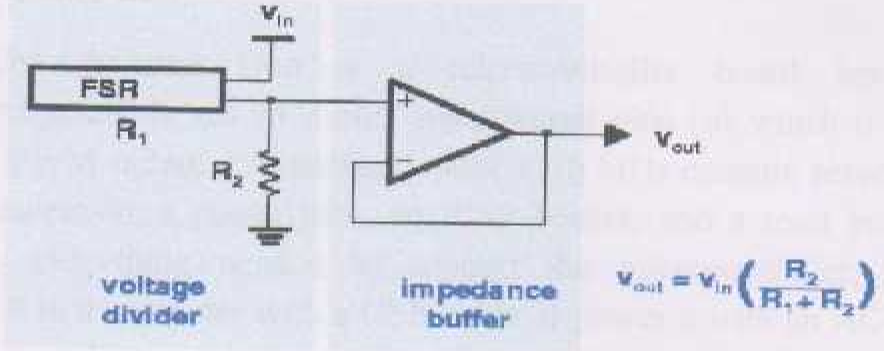

Figure (3.21) :- Basic Flex Sensor Circuit.

After fixed this flex sensors on the other right hand finger, we have become a five analog signals from the five fingers, and we connect after each flex sensor resistance of 1 KΩ for protection, then we will use are as an analog inputs to the first microcontroller, as shown in figure (3.22).

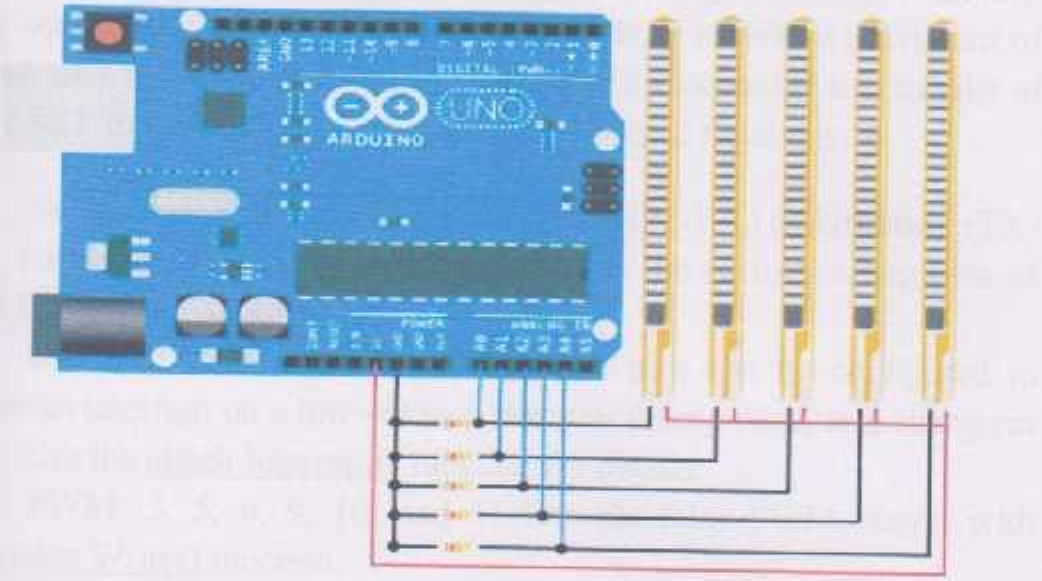

Figure (3.22):- How to Connect The Flex Sensor With a Microcontroller.

3.2.2 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started, as shown in figure (3.23)

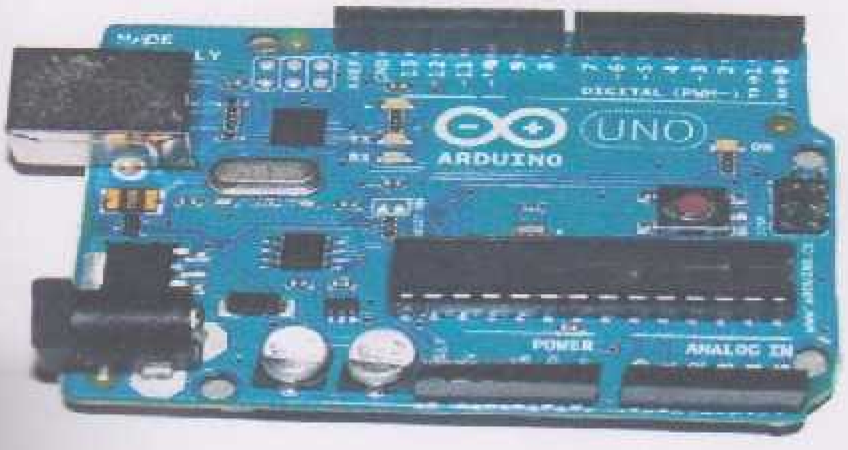

Figure (3.23):- Arduino Uno. [24]

Each of the 14 digital pins on the Uno can be used as an input or output, using pin Mode(), digital Write(), and digital Read() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 KΩ. In addition, some pins have specialized functions:

- **Serial**: 0 (RX) and 1 (TX). Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts**: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attach Interrupt() function for details.
- **PWM**: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analog Write() function.
- **SPI**: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.

The arduino is used as the core of the system, it captures analog signals from flex sensors, converts them to digital through the integrated ADC module and do the recognition process by using a lookup table; when the letter is recognized, a corresponding digital value will be sent via the TX pin (integrated serial module) to the XBee transmitter serial module board, by write asuitable code, we will explain it in the next chapters.

3.2.3 XBee Module

XBee is a wireless RF module using the wireless communication standard 802.15.4; it has longer range than Bluetooth but lower power consumption than WiFi (802.11). It has a 250 kbps RF data rate. It operates at 2.4 GHz. The XBee modules have sleep modes for extended battery life.

We will use two pieces of the XBee module, one as a transmitter and the last one as a receiver, and now we will explain how to connect are with each other based on the figure (3.24).

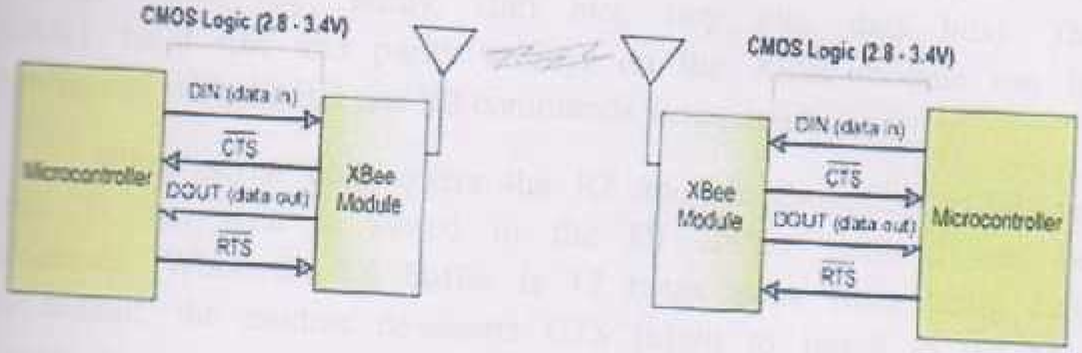

Figure (3.24):- System Data Flow Diagram in a UART-Interfaced Environment.

3.2.3.1 XBee transmitter

We will connect the first microcontroller with the XBee transmitter, such that; Devices that have a UART interface can connect directly to the pins of the RF module, data enters the module UART through the DI pin (pin 3) as an asynchronous serial signal. The signal should idle high when no data is being transmitted.

Each data byte consists of a start bit (low), 8 data bits (least significant bit first) and a stop bit (high), the serial bit pattern of data passing through the module, as shown in figure(3.25).

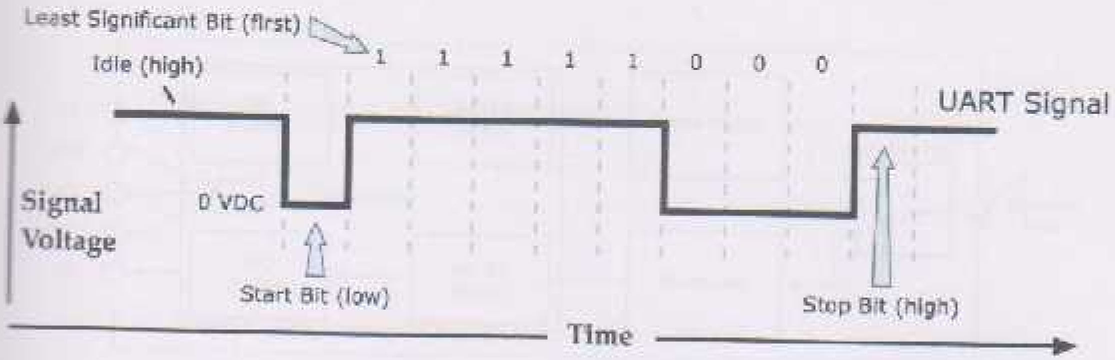

Figure (3.25) :- UART Data Packet 0x1F (Decimal Number ‖ 31‖) as Transmitted Through The RF Module. [25]

Serial communications depend on the two UARTs (the microcontroller's and the RF) to be configured with compatible settings (baud rate, parity, start bits, stop bits, data bits). The UART baud rate and parity settings on the XBee module can be configured with the BD and SB commands, respectively.

When serial data enters the RF module through the DI pin (pin 3), the data is stored in the DI Buffer until it can be processed, When the DI buffer is 17 bytes away from being full; by default, the module de-asserts CTS (high) to signal to the host device to stop sending data [refer to D7 (DIO7 Configuration) parameter, CTS is re-asserted after the DI Buffer has 34 bytes of memory available.

Case in which the DI buffer may become full and possibly over flow; if the module is receiving a continuous stream of RF data, any serial data that arrives on the DI pin is placed in the DI Buffer, the data in the DI buffer will be transmitted over-the-air when the module is no longer receiving RF data in the network.

3.2.3.2 Xbee Reciever

When RF data is received, the data enters the DO buffer and is sent out the serial port to a second microcontroller, once the DO Buffer reaches capacity, any additional incoming RF data is lost, as shown in the figure (3.26).

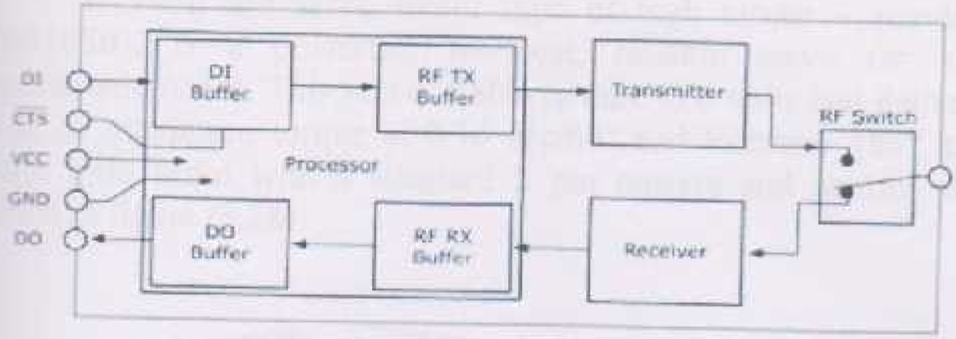

Figure (3.26):- Internal Data Flow Diagram. [25]

The second microcontroller will enter it two different inputs, the first one come from EMG device to control the motor movement to move the hand, and the last one come from the XBee receiver module to control a five servo motors to move the fingers.

3.2.4 Servo Motors

We have to control the servo motors using the microcontroller, so that when we move the fingers of the other hand right, servo motors moves are allowed to move the fingers of the infected hand also moved a similar right Other Hand.

Where they put the servo motors on the soles of the hand inside the plastic box, and connects with shaft every one of them copper wire is strong and taut dramatically transmission as Hey, connecting joints ferrous mounted on the fingers of the hand infected and in this way we were able to move the fingers of the hand are easy to smooth close to reality, as shown in figure (3.27).

Figure (3.27):- Servo Motor Place in The Design.

We will use servo motor type of high torque – standard size (**FS5105B**), is a powerful, low-cost, reliable servo for all your mechatronic needs. This servo is able to take in 6 volts and deliver 83.47 oz-in of maximum torque at 0.16 sec/60° and Rotation 180°, this is a tough little servo with a standard 3 pin powers and control cable, as shown in figure (3.28).

Figure (3.28):- Servo Motor High Torque - Standard Size (FS5105B). [26]

We used servo motors because it contains many advantages such as; a clear torque advantage for servo motors at the high speeds gained by electric actuators, When high speed and high torque is required, a significant edge goes to these type of motors, and A servo motor continuously reads in current position data vs. the commanded position data and provides current to the motor proportional to the degree of error. In summary, the inherent use of an encoder aids the servo motor in its ability to have a position fault error limit, ther clear advantage of using a servo motor is the capability of achieving high speed at relatively high torque values over a much larger amount of time.

The motor can better handle dynamic loading applications. Due to this extended time, a servo motor is capable of providing short bursts of additional torque over the entire speed spectrum of cylinder length. In situations where the load is dynamic, the reserve of torque allows more changing and flexible motion control, a major weakness of servo motors is its cost due to having the complex encoder feedback device in the hardware. All of the performance capability comes at a premium cost.

3.2.5 Power Circuit

3.2.5.1 Battaries (Power Supplies)

Any project in the electric field of industrial or other, where electronic or electrical pieces need a feed source for the work, these pieces differ in the amount of effort they need.

In our project there are several electric or electronic pieces need to source feed and vary the amount of effort they need, for example to the servo motors need to 5 V and 12 V need amplifiers, microcontrollers also require 5 V and XBee needs 3.3 V, so we choose the battery gives a larger effort our piece and we distribute the voltage on the other pieces by using the voltage dividers to reach the effort required for each piece.

Our project is a exoskeleton of hand for the paralyzed, the paralyzed person can't always stay close to the source of nutrition, so we will use 12 V portable battery, we fix it on the side of the person to facilitate the unimpeded movement, comes with this battery charger for shipment when it will be discharges, as shown in figure (3.29).

Figure (3.29):- Portable Battery 12v DC. [27]

3.2.5.2 Voltage Regulators

Regulators provide a power source which remains very close to a fixed value, independent of the load placed on it, provided that the current drawn doesn't exceed the rating of the device, the minimum and maximum output voltage specification for fixed voltage regulators indicated the values which can be expected with variations in load on the device, the same specification for adjustable regulators indicated the range of voltage output which can be achieved through external component.

We used two types of voltage regulators, the first LD1117-3.3 V for the XBee module, and the other is LM1084 5 V for the microcontrollers and the servo motors, as shown in figure (3.30).

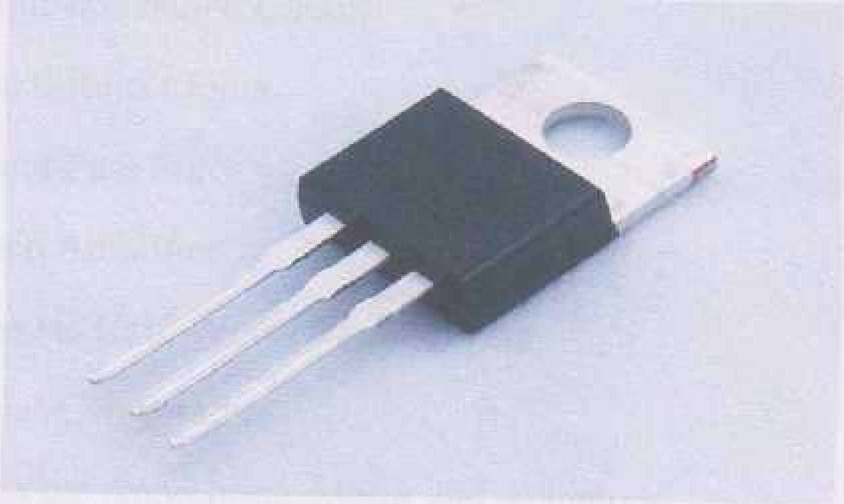

Figure (3.30):- Voltage Regulators. [28]

4 Chapter Four

Calculations and Measurements

In this chapter we will calculate every input and output value of the devices to go out with the wanted results, for EMG device and DC motor practically.

4.1 EMG Device

4.1.1 Pre-Amplifier

The pre-amplifier circuit (Instrumentation amplifier usually with Av=10) is used for picking up the unipolar EMG signals.

And we used IC represent this circuit called AD 620, as shown in figure (4.1a+b)

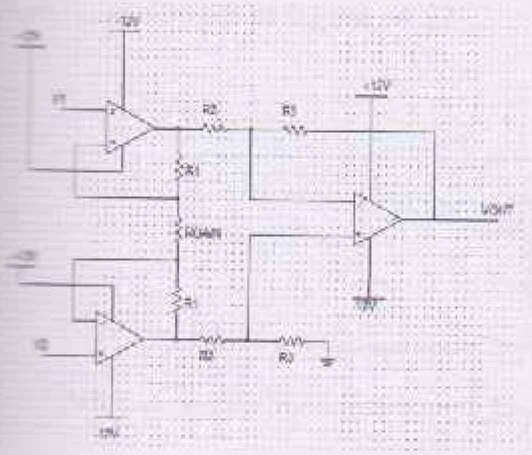

Figure (4.1a):- Pre-Amplifier Circuit Implementation.

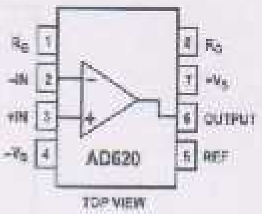

Figure (4.1b):- AD620

Where R_g the gain resistance is is used to determine the gain of the amplifier.

$$A_v = \frac{49.4\ k\Omega}{R_g} + 1$$

We used gain (A_v) equal 10, then

$$10 = \frac{49.4\ k\Omega}{R_g} + 1 \Longrightarrow R_g - 5.48\ k\Omega$$

$R_g = 5.48\ k\Omega$,is used to control in the gain .

So, as tacked previous a potential waveform with an amplitude of 20-2000 μV

Then V_{in}=20-2000 μV, and Av=10.

Then V_{OUT} of the pre-amplifier = 20-2000 μV * 10 = 0.2-20 mV. [31]

4.1.2 Optical Isolation Circuit

Optical connection between the preamplifier and the band-reject filter (Av=1), as shown in figure (4.2).

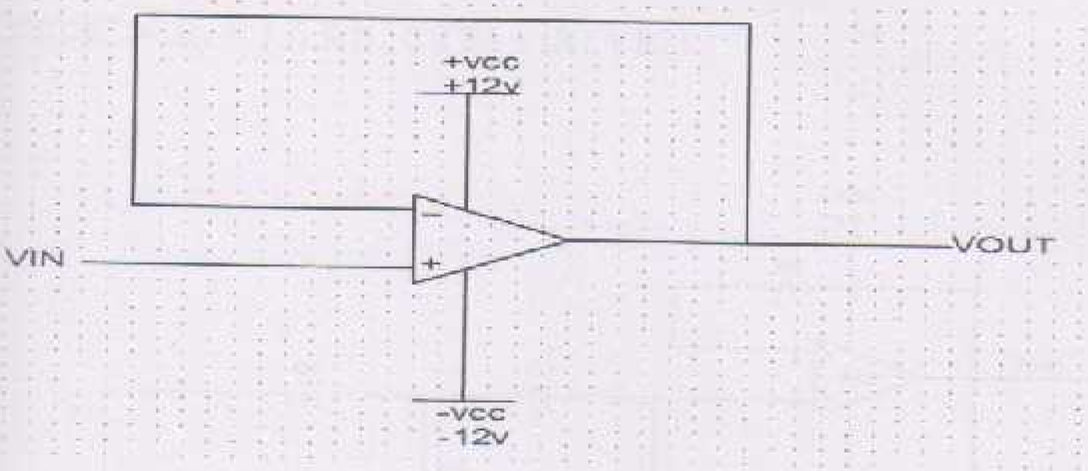

Figure (4.2):- Isolation Circuit.

Av = 1, then $V_{in} = V_{OUT}$

So, V_{OUT}= 0.2-20 mV.

4.1.3 Band-Reject Filter

The band-reject filter is used to remove the noise from power line (50 or 60 Hz).

- If (C_1=C_2, R_1=R_2, R_1=2R_3 and C_3=2C_1), as shown in figure(4.3) then :

The center frequency can be calculated by:

$$f_c = \frac{1}{2\pi C1R1} = 50\ Hz$$

Let C_1 = 1μF = C_2 ⟹ C_3 = 2 μF , then

50 = 1/[(6.28* 1μF)* R_1] ⟹ R_1 = 3.2KΩ = R_2

⟹ R_3 = 1.6 KΩ , 0 < R4 < (R1 + R2).

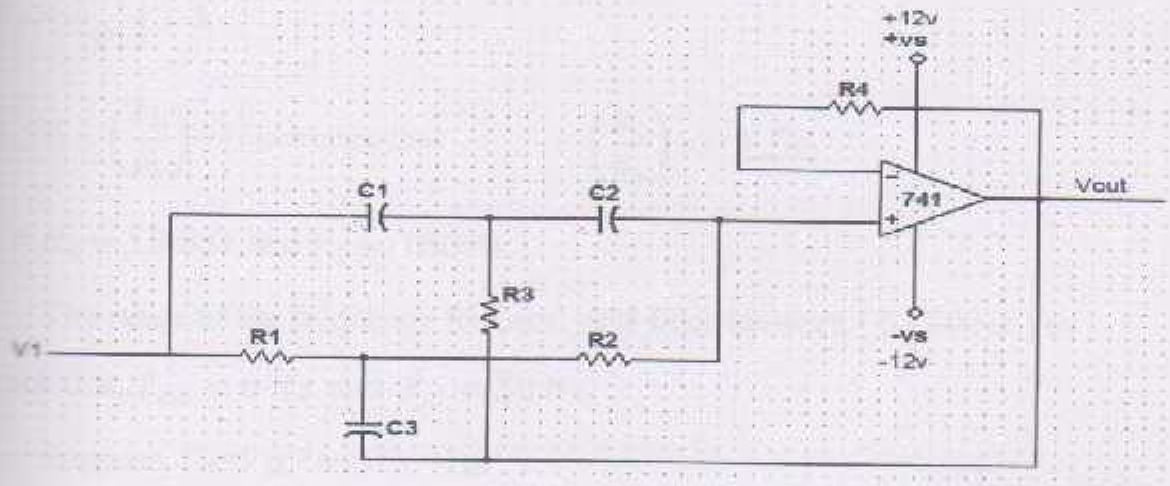

Figure (4.3):- Band-Reject Filter Circuit. [31]

4.1.4 Band-Pass Filter

The op-amp is used to construct an active 2nd order low-pass and high-pass filters. As shown in figure (4.4).

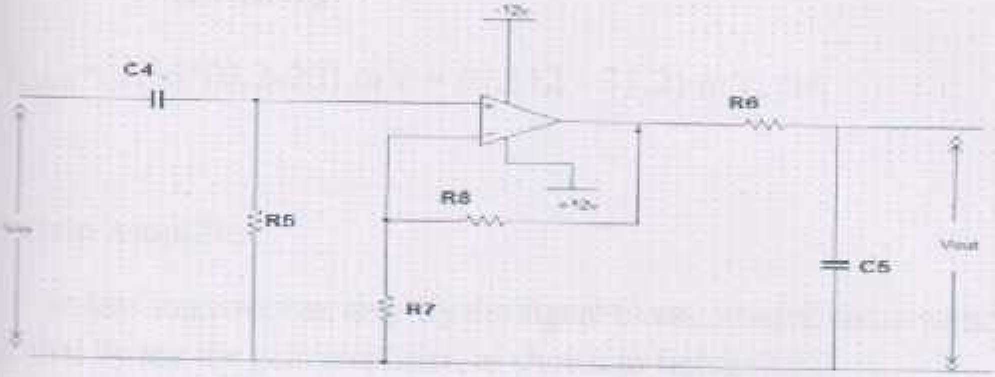

Figure (4.4):- Active Band-Pass Filter Circuit.

In Band-Pass Filter must a Av=1.56, to keep not increasing the noise of the signal.

$$A_v = \left(\frac{R_8}{R_7}\right) + 1$$

$$1.56 = \left(\frac{R_8}{R_7}\right) + 1 \Longrightarrow \left(\frac{R_8}{R_7}\right) = 1.56$$

Let $R_8 = 100k\Omega$ and $R_7 = 180k\Omega$

- The range of the frequency for band pass filter between (6 - 30 Hz) so ,

Such that, $F_{CH} = 6\ Hz$ and $F_{Cl} = 30\ Hz$.

- Suppose, C_4=1 μF and C_5 =1μF.

Such that, $F_{CH} = \frac{1}{2\pi R_5 C_4}$, then :

$$6 = \frac{1}{2*3.14*1\ \mu F*R_5} \Longrightarrow R_5 = 26.5\ k\Omega.$$

And, $F_{CL} = \frac{1}{2 * \pi * R_6 * C_5}$

Then, $30 = \frac{1}{2*3.14*1uF*R_6}$ $\Longrightarrow$ $R_1 = 5.3\ k\Omega$

So, V_{OUT} = 1.56*(0.2-20) mV = (0.312 - 31.2) mV. [29]

4.1.5 Gain Amplifier

In this stage we can amplify the signal to any wanted value without any noise, that by use the gain amplifier, as shown in figure (4.5).

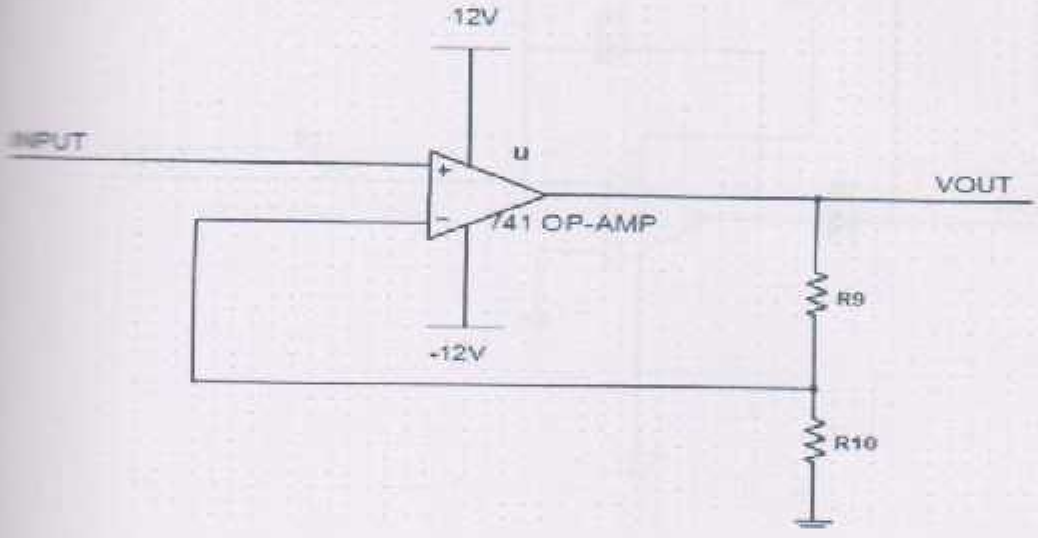

Figure (4.5):- Gain Amplifier Circuit.

As shown in figure (5.5), Suppose $R_1 = 100\ K\Omega$, $R_2 = 700\Omega$, then :

$$A_v = \frac{R_9}{R_{10}} + 1 = \frac{100K\Omega}{700\Omega} + 1 = 145.$$

Then, V_{OUT} = 145 * (0.312-31.2) = (0.045 – 4.5) V. [31]

4.1.6 Precise Half-Wave Rectifier Circuit

In this stage, we aim to take the positive part of the signal, so we will use the precise half-wave rectifier, as shown in figure (4.6)

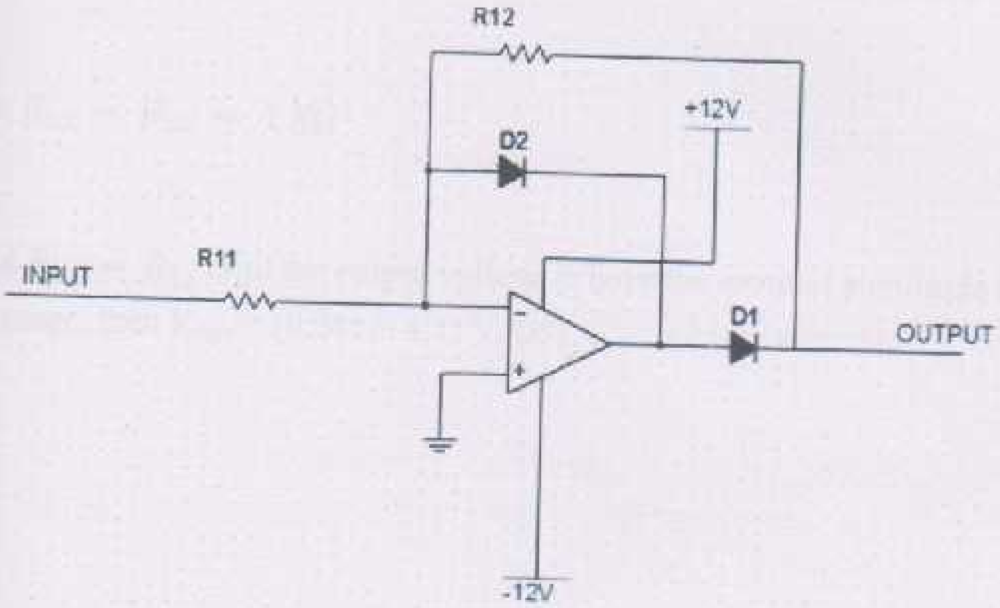

Figure (4.6):- Precise Half-Wave Rectifier Circuit.

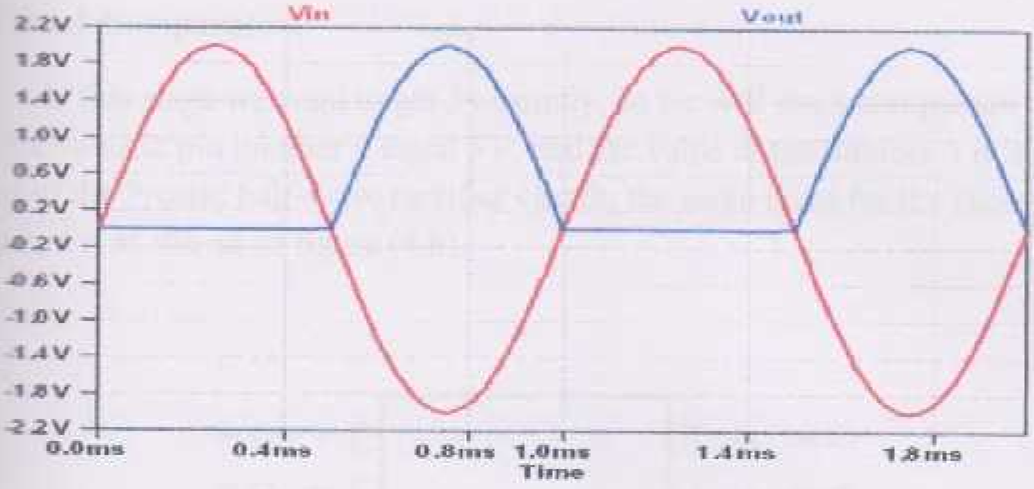

Figure (4.7):- Input-output Relationship of Half-Wave Rectifier Circuit.

Assume $R_{11} = R_{12} = 1\ K\Omega$

We used $R_{11} = R_{12}$ until the output voltage is have the same of amplitude for input voltage, then V_{cmr}= (0.045 – 4.5) V. [31]

4.1.7 Dual-Comparator

In this stage we want to get 5v exactly, so we will use a comparator, such that, the value at pin number 4 equal 5V, and the value at pin number 5 it is the output of the Precise half-wave rectifier circuit, the same thing for the second comparator, as shown in figure (4.8).

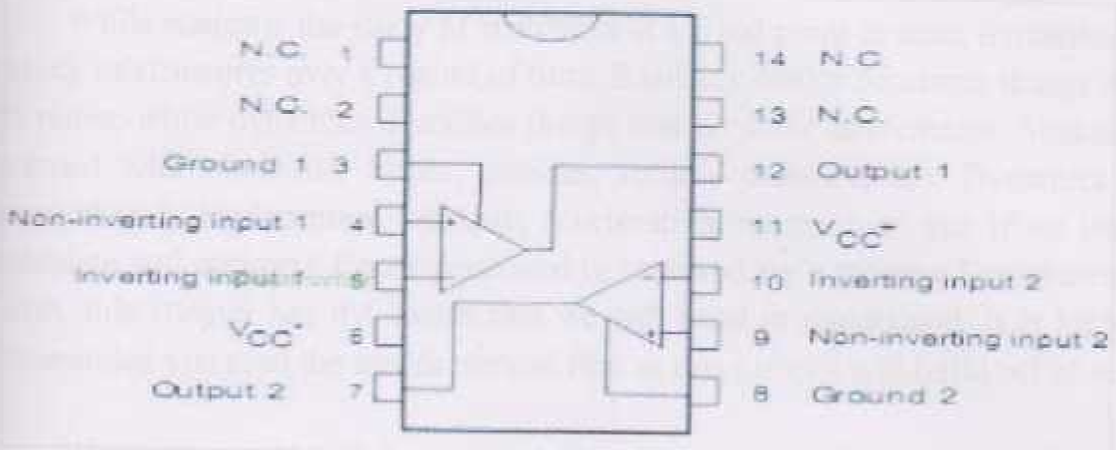

Figure (4.8):- LM319D Dual-Comparator Implementation.

Finally, because the output of the precise half-wave rectifier circuit is less than 5V always, then the output of the EMG System equal 5V.

Selection the Appropriate Motor and Actuators

For precise calculations of the appropriate motor that being used for moving exoskeleton hand, an analyzes of the forces acting on the arm being conducted in order to choose the motor can able to move this structure . Therefore there is a need to understand the concept of static and dynamics equilibrium and solving related tasks.

While statics is the study of structures at a fixed point in time, dynamics is the study of structures over a period of time. Basically statics describes things that don't move, while dynamics describes things that do some movements. Statics is concerned with moments, forces, stresses, torque, pressure, etc. Dynamics is concerned with displacement, velocity, acceleration, momentum, etc. If we want to calculate and optimize forces generated or required for a moving Exo-skeleton for arm, this chapter has the basics that we will need to understand. It is highly recommended you read the statics tutorial first as this tutorial will build off of it.

When one undertakes an analysis of any human movement, one must take into account a number of forces acting on the system, to simplify the problem for better understanding, a free body diagram is often used. A free body diagram is a stick figure drawing of the system showing the vector representations of the external forces acting on the system. In biomechanics, the system refers to the total human body or parts of the human body and any other objects that may be important in the analysis [32].

4.2.1 Static Analysis

The free body diagram as in figure (4.9), showing the vector representations of the external forces acting on the system.

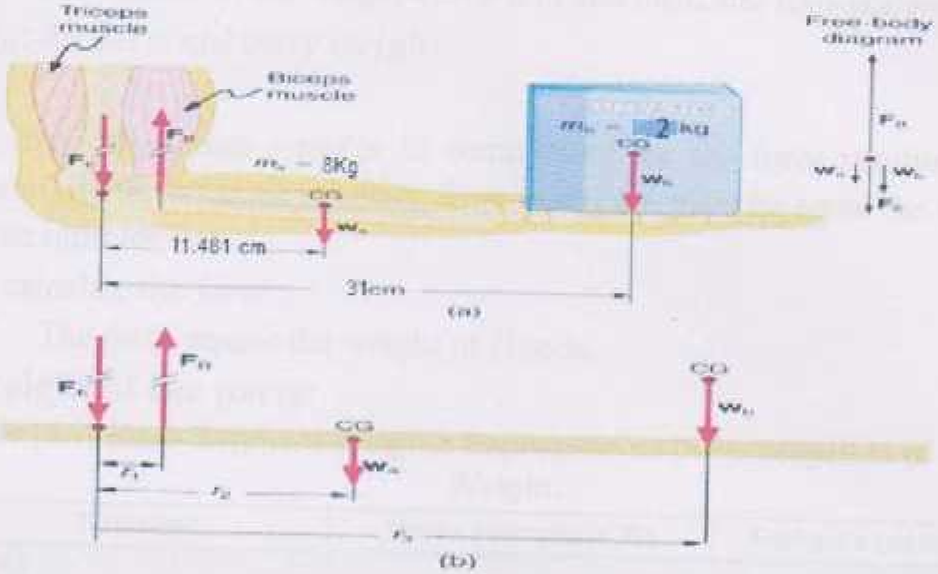

Figure (4.9):- Analysis Forces for The Free Body Figure Diagram of The Arm.

The static case is devoted to systems at rest or moving at a constant velocity. In both of these situations, the acceleration of the system is zero. When the acceleration of a system is zero, the system is said to be in equilibrium. A system is in equilibrium when, as stated in Newton's first law, it remains at rest or it is in motion at a constant velocity. [33]

In translational motion, when a system is in equilibrium, all forces that are acting on the system cancel each other out, and the effect is zero. That is, the sum of all forces acting on the system must total zero. This is expressed algebraically as:

$\sum F_{system} = 0$ .... (1).

$F_B \quad F_E \quad W_A \quad W_B = 0$ .... (2).

Where:

F_B : force resulting of biceps muscles.

F_E: force resulting of triceps muscles.

W_A: The outcome of the weight of the arm and hand and Exo-skeleton.

W_B : *An external body weight.*

We will design a motor to compensate for the force resulting from the muscles. The force/torque resulting from the motor must be equal the force/torque from the muscles.

- To calculate the force :

  The force equals the weight of objects.

- Weight of the parts:

Table (4.1) Mean Segment Weights Expressed as Percentages % of Total Body Weight.

Segment	Males (sample = 35)	Females (sample = 73)
Head	8.26	8.20
Whole trunk	55.10	53.20
Thorax	20.10	17.02
Abdomen	13.06	12.24
Pelvis	13.66	15.96
Total arm	5.77	4.97
Upper arm	3.25	2.90
Forearm	1.87	1.57
Hand	0.65	0.50
Forearm and hand	2.52	2.07
Total leg	16.68	18.43
Thigh	10.50	11.75
Leg	4.75	5.35
Foot	1.43	1.33
Leg and Foot	6.18	6.68

1) **Arm:**

Arm mass varies from person to person and depends on the total mass of the human body. We will calculate the weight of the arm based on previous studies by Plagenhoef in 1983 accomplishing that applied on a sample of 37 men and 100 women [34], as table (4.9).

Weight = mass * acceleration of gravity.
We will be assumed the patient is male

And can be calculate as:

a) forearm :

Let body mass = 76.5 N, then the body weight equal:

Body weight = 76.5 *9.81 = 750 kg. N/s^2 = 750 N

The Forearm and Hand weights can be calculate as:

Forearm weight = 1.87% * total body weight

= 0.0187* 750 N = 14.025 N (⇩)

b) Hand :

Hand weight = 0.65% * total body weight.

= 0.0065*750 = 4.875 N (⇩)

2) Exo-skeleton and other objects:

Assume; weight = 80 N (⇩)

Total force = total weight = forearm weight + hand weight + Exo-skeleton and other objects weight.

Total force = 14.025 + 4.875 + 80 = 98.9 N. ⟹ Total mass = 10 Kg.

Therefore, you must be the force resulting from the motor greater or equal to the sum of the forces acting on the arm to achieve equilibrium.

F_M> = **98.9 N.**

- To calculate the torque :

Torque equals applied force multiplied by the perpendicular distance (R) from the line of action of the force to the pivot point.

To measure the perpendicular distance between the line of action of the force and the pivot point we must identify the length of arm, then we identify the center of mass for arm.

Depending on previous studies by Plagenhoef in 1983 accomplishing that applied on a sample of 37 men and 100 women [25], as tables (4.2+4.3).

- Length of arm:

1) Forearm:

Length of forearm = 0.157 * total human length.
Let, total human length = 170 cm.
Then, length of forearm = 0.157 * 170 = 26.7 cm.

2) Hand:

Length of hand = 0.0575 * total human length.
Then, length of hand = 0.0575 * 170 = 9.775 cm.

Table (4.2) Mean Segment Lengths Expressed as Percentages (%) of Total Body Height.

Segment	Males (sample = 35)	Females (sample = 73)
Head	10.75	10.75
Trunk (hip to shoulder)	30.00	29.00
Thorax	12.70	12.70
Abdomen	8.10	8.10
Pelvis	9.30	9.30
Upper arm	17.20	17.30
Forearm	15.70	16.00
Hand	5.75	5.75
Thigh	23.20	24.90
Leg	24.70	25.70
Foot	4.25	4.25
Biacromial	24.50	20.00
Bi-iliac	11.30	12.00

After identify the length of the forearm and the hand, now we can identify the center mass of each.

- Center of mass :

Forearm center of mass = 43% * long of forearm

$= 0.43 * 26.7 = 11.481$ cm.

Hand center of mass = 46.8 % * long of hand

$= 0.468 * 9.775 = 4.5747$ cm.

Let: - Exoskeleton Length = 36.5 cm.

- Exoskeleton Center of Mass = 18.25 cm.

Table (4.3) Segmental Center of Gravity Locations Expressed as Percentages (%) of Segment Lengths Measured From The Proximal Ends.

Segment	Males (sample = 7)	Females (sample = 9)
Head and neck	55.0	55.0
Trunk	63.0	56.9
Upper arm	43.6	45.8
Forearm	43.0	43.4
Hand	46.8	46.8
Pelvis	5.0	5.0
Abdomen	46.0	46.0
Thorax	56.7	56.3
Thigh	43.3	42.8
Leg	43.4	41.9
Foot	50.0	50.0
Abdomen and pelvis	44.5	39.0

Then, total torque = $\sum(F * R)$ = [(forearm weight * Center of mass for forearm weight) + (Hand weight * Center of mass for hand) + (Exo-skeleton and other objects * Center of mass for Exo-skeleton and other objects)].

Total torque = [(14.025 N * 0.11481) + (4.875 N* 0.045747) + (80 N * 0.1825)]

= 1.61021 + 0.2230167 + 14.6

= 16.43 N.m

4.2.2 Dynamic Analysis

The above equations only deal with the case where the Exo-skeleton is being held horizontally (not in motion). For the arm to move from a rest position, acceleration is required. To solve for this added torque, it is known that the sum of torques acting at a pivot point is equal to the moment of inertia (I) multiplied by the angular acceleration (alpha). [35]

- To calculate the force acting on the axis:

$F_T = m_t * \alpha * r_G$................equ.(1)

To calculate α:

$\alpha = \frac{a}{r_G}$ ....equ. (1.1) ; but :

$a = \frac{v}{t}$ .... equ. (1.2)

We must assume that the values of the time be suitable for moving the hand properly. Then;

Assume:
t = 5 second.

To find v:

$v = \frac{l}{t}$ ....equ (1.3); but:

We will calculate the maximum circular distance traveled round hand.

Then be angle = 90 , so it becomes the length of the circular Arc, as shown in figure (4.10).

$$l = \frac{\pi}{4} r_G = \frac{\pi}{4} * 0.182.$$

$$= 0.14326\, m \qquad \dots\dots\dots \quad sub.\, in\, equ(1.3)$$

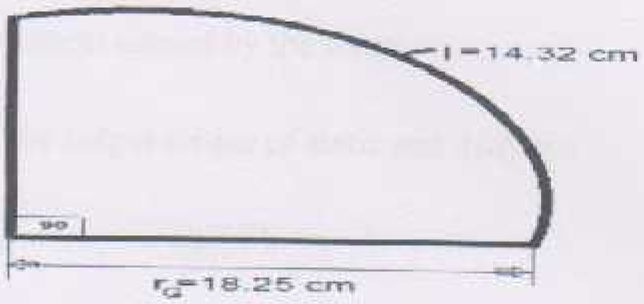

Figure (4.10):- Path Movement of The Arm.

$$v = \frac{l}{t} = \frac{0.14326}{5} = 0.02865\ m/S \qquad \dots\dots\dots \ sub.\, in\, equ\ (1.2)$$

$$a = \frac{v}{t} = \frac{0.02865}{5} = 0.00573\ m/s^2 \qquad \dots\dots\dots \ sub.\, in\, equ(1.1)$$

$$\alpha = \frac{a}{r_G} = \frac{0.00573}{0.1825} = 0.0134\ 1/s^2 \ \dots\dots\dots\dots\dots \ sub.\, in\, e\, qu\ (1)$$

$$F_r = m_t * \alpha * r_G = 10 * 0.0314 * 0.1825 = 0.0573\ \frac{kg * m}{s^2}$$

Icon Symbols used in equations:

m_t: Total mass (hand and forearm and Exo-skeleton).
α : angular acceleration .
r_G : Distance between shaft of motor to force acting on center of mass.
a : Acceleration.
v : velocity .
t : time .
l : The length of a quarter circular arc.

- To calculate the moment caused by the force:

Moment is equal to the output torque of static and dynamic

$\sum M_G = I_G * \alpha + T_S$ .... equ(2).

$$I_G = \frac{m_t * l^2}{12} = \frac{10 * (0.365)^2}{12} = 0.111\, kg.m^2 \ldots\ldots\ldots sub. in\ equ(2)$$

$$\sum M_G = I_G * \alpha + T_S = 0.111 * 0.0314 + 16.43 = 16.4335\, N.m$$

Where;

T_S : *output torque of static analysis.*
I_G:*moment of inertia .*

Safety factor: we must add additional torque to the total output torque for safety as equals:
Safety factor = 1.5 * total output torque.
= 1.5 * 16.4335 = 24.65 N.m

And to supplement the process of selecting the appropriate DC motor, speed must be determined:

- To find speed:

$n = \frac{w*60}{2\pi}$ ... ... equ(3).

$w = \frac{v}{r_G} = \frac{0.02865}{0.1825} = 0.157\ rad/seconde$ .... sub. in equ(3).

$n = \frac{0.157*60}{2\pi} = 90\ rps$

Where:
n: speed of motor in rpm.
w: angular speed .

⟹ The appropriate DC motor speed and torque equal:
Speed = 90 rps.
Torque = 24.65 N.m

4.3 Gear Calculation

Motor driven systems usually have optimal motor speeds at which the motor operates with the greatest power and efficiency. These motor speeds are expressed in rotations per minute (RPM) of the motor shaft. In many applications, this optimal motor speed is not the optimal speed (RPM) at which the load should be driven. Gearing is used in the form of differently sized gears. These gears are attached to the motor shaft and load shaft, and are coupled together by inter-meshed teeth. This produces a gear ratio, which is a direct measure of the ratio of motor shaft rotational speed to load shaft rotational speed. The gear divided into two parts, a drive gear and driven gear.

A drive gear attached to the motor shaft and a driven gear attached to the load shaft.

1) Gear ratio:

- Number of teeth on each gear used in the system:

Gear ratio is determined starting with the drive gear, so it should be noted which gear in the gear load, counting from the drive gear to the driven gear, has what number of teeth, figure(4.11).

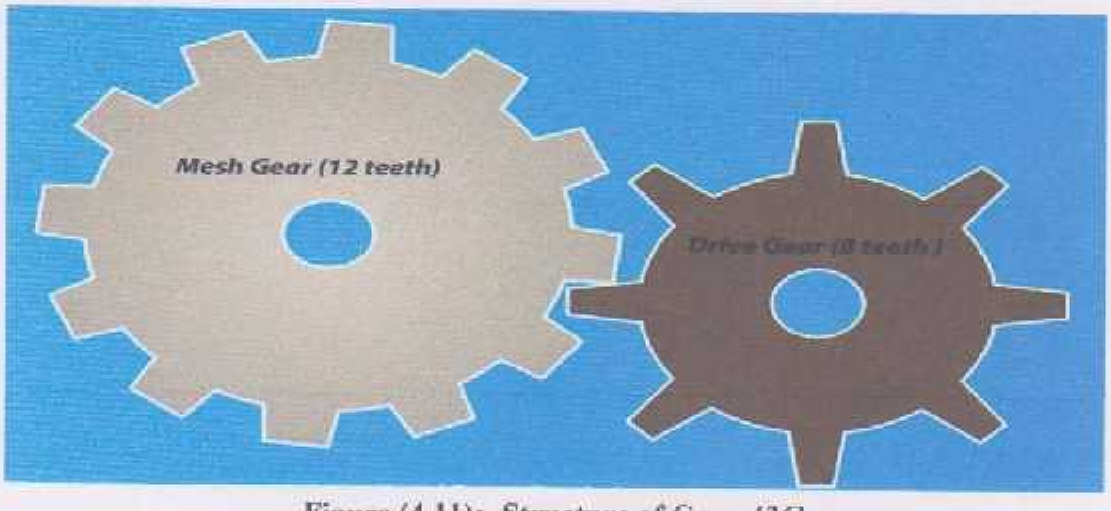

Figure (4.11):- Structure of Gear. [36]

And can be calculate as:

$$\text{Gear Ratio} = \frac{number\ of\ teeth\ for\ driven}{number\ of\ teeth\ for\ drive} = \frac{12}{8} - 1.5$$

That means when motor turns 1 time the gear load turns 1.5 time.

2) Gear efficiency (η):

$$\eta = \frac{\text{input power}}{output\ power} = \frac{input\ speed * input\ torque}{output\ speed * output\ torque} = \frac{w_1 * p_1}{w_2 * p_2}$$

Output power = η * input power

Assume η=0.8

Output power=0.8*$T_1 * w_1$

Output from the previous equations T_1 =24.65 and $w_1 = 0.157$

Output power=0.8*$T_1 * w_1 = 0.8 * 24.65 * 0.157 = 3.1\ watt$

After selecting the appropriate DC motor and gear we will link this gear with Exo-skeleton.

4.4 Servo Motor Calculation

To calculate the torque load of the finger to select the suitable motor is capable of pulling the finger, was chosen motor is capable of pulling times a pregnancy resulting from the withdrawal of the largest and longest finger, a middle finger in the hand, and thus the rest of the motor is able to pull the finger because the other fingers smaller and shorter than the middle finger, therefore calculations were only for the middle finger of the hand.

For adults, the weight of the middle finger of the hand almost = 150 gm, and the distance from the center of mass of the finger to the end of the finger almost = 8cm.

So, M = 150 g and D = 8 cm, where:-

M:-the weight of the middle finger of the hand. (Kg)

D:-the distance b=from the center of mass of the finger to the end of it. (m)

T:-torque load of the finger. (N.m)

Then, $T = M.D$

$= 150\ gm * 8cm = 1200 gm.cm = 0.012\ N.m.$

To a motor can carry a hand when it carry a light load, was double the torque load, then the total load torque = 5*0.012 = 0.06 N.m.

So were selected servo motors torque is equal 0.34 N.m according to datasheet for it.

5 Chapter Five

Design and Results

Will detailed explanation the work process that has been done as the form of steps.

5.1 Mechanical Design

5.1.1 Hand Exoskeleton Design

Step 1:- Polyethylene is used for forming artificial arm that resembles natural hand, as shown in figure (5.1).

Figure (5.1):- Forming Artificial Arm Using Polyethylene.

Polyethylene (PE) resins are a general class of thermoplastics produced from ethylene gas. Ethylene gas is derived from the cracking of natural gas feed stocks or petroleum byproducts. Under broad ranges of pressures, temperatures and catalysts (depending PE type), ethylene generally polymerizes to form very long polymer chains, this article is too harsh, when placed in hot water becomes very soft take it out, and shape in any way and after a while takes the desired shape, as shown in figure (5.2).

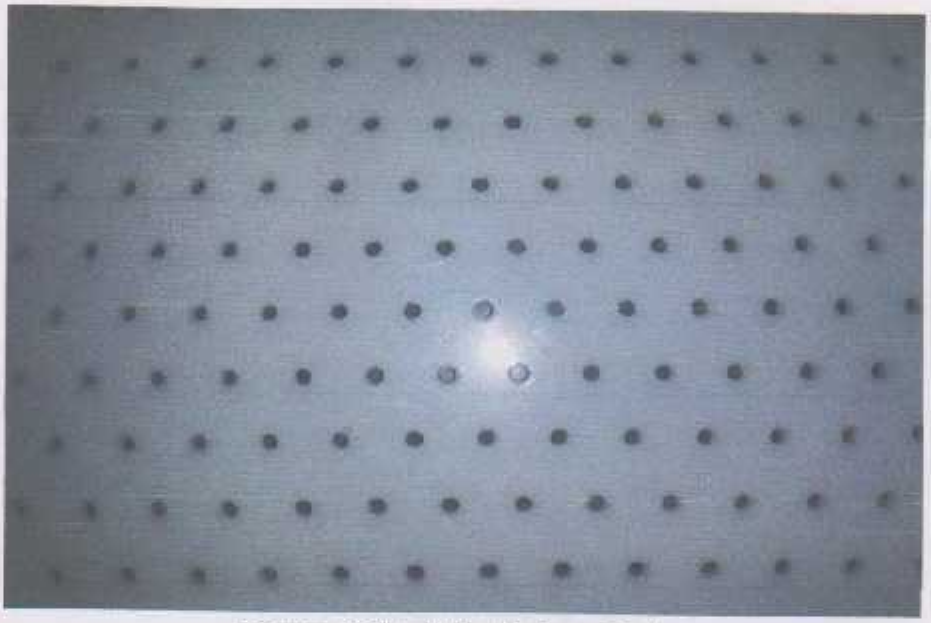

Figure (5.2):- Polyethylene Plate.

It was also a box of polyethylene, which is a five of servo motors with a specific shape as shown in the figure (5.3), where not inconsistent shafts of this motors with each other.

Figure (5.3):- Fixed The Five Servo Motor in Box That Made of Polyethylene.

After that, dish of sponge on the parties to the pieces to ensure the protection of the patient from scratch, coverage pieces of leather plate to give a form is nice and comfortable to the patient, as shown in figure (5.4).

Figure (5.4):- Pieces of Polyethylene Leather Covered.

Then we installed a DC motor on the first piece of figure (5.4), and connect the shaft of motor with gear, and connect a gear with another gear installed on the elbow by belt, then connect the second gear with the second piece, as shown in figure (5.5).

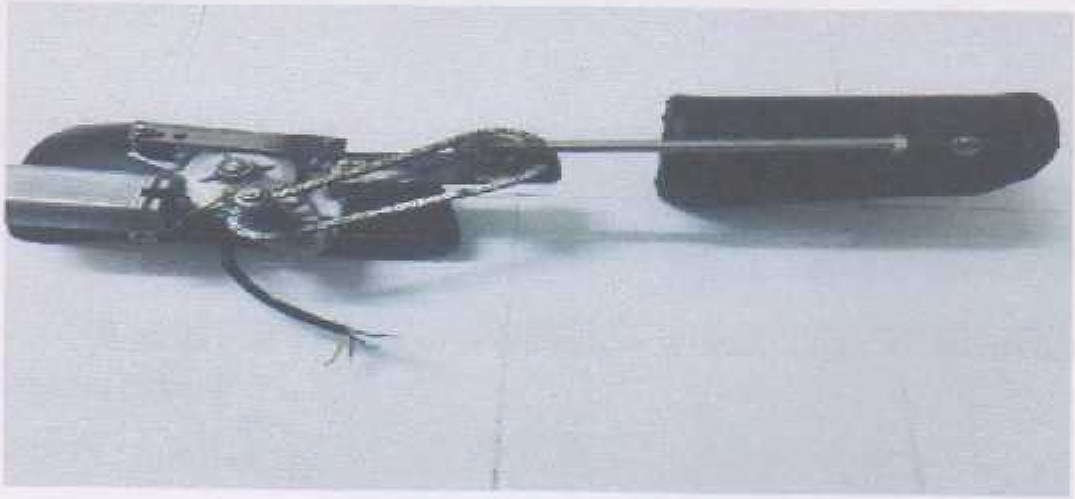

Figure (5.5):- Mechanical Design of Hand.

5.1.2 Fingers Exoskeleton Design

Was installed the Flex sensors on glove over the fingers of the right hand, as shown in figure (5.6).

Figure (5.6):- Installed The Flex Sensors on The Fingers

Was formed 3 pieces of polyethylene for each finger of the hand, as shown in figure (5.7).

Figure (5.7):- Formed Fingers of Hand Using Polyethylene.

And was installed each piece using the stud to get stretched and removed when needed, and the connection between these pieces by a small spring replace the hinge, as shown in figure (5.8).

Figure (5.8):- Installed Each Pieces Using Stud.

And each finger has been linked with a servo motor custom for him using a very strong plastic cord, as shown in figure (5.9).

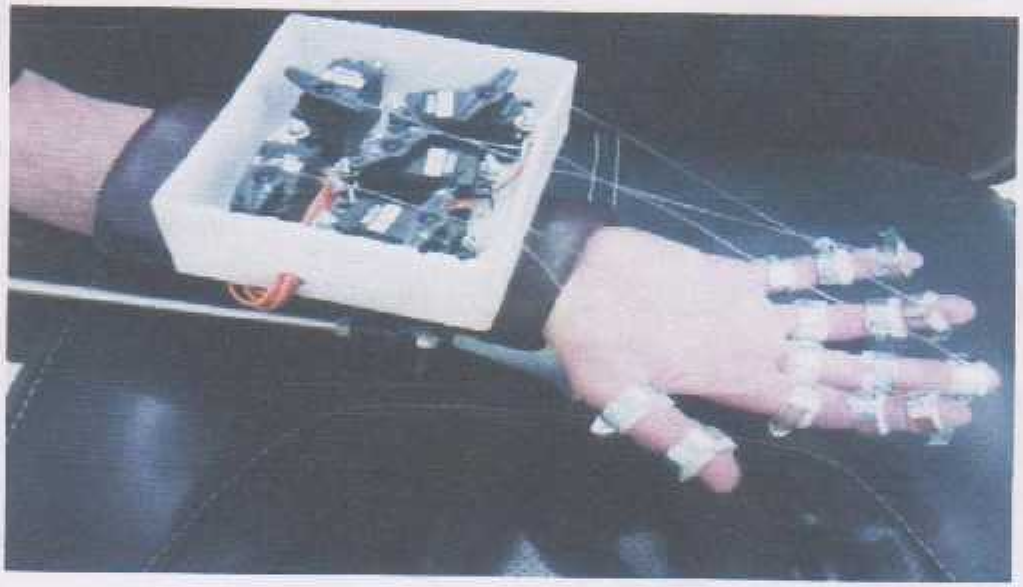

Figure (5.9) :- Connected The Servo Motors With The Fingers.

Finally, to come up with a complete mechanical design of the project, as shown in figure (5.10).

Figure (5.10):- Complete Mechanical Design of Exoskeleton.

5.2 Electrical Design

The electrical design of the project was built in 3 circuits, and these circuits have been designed using proteus 8 professional program, these circuits are:-

5.2.1 EMG Circuit

This circuit is designed to extract electrical muscle signal, then amplified and filtered this signal to introduced to microcontrollers to control the movement of the DC motor, where have pre-amplifier, optical isolation circuit, band-reject filter, band-pass filter, gain amplifier, half-wave rectifier and dual-comparator, where is drawn using proteus 8 professional program as schematic, as shown in figure (5.11).

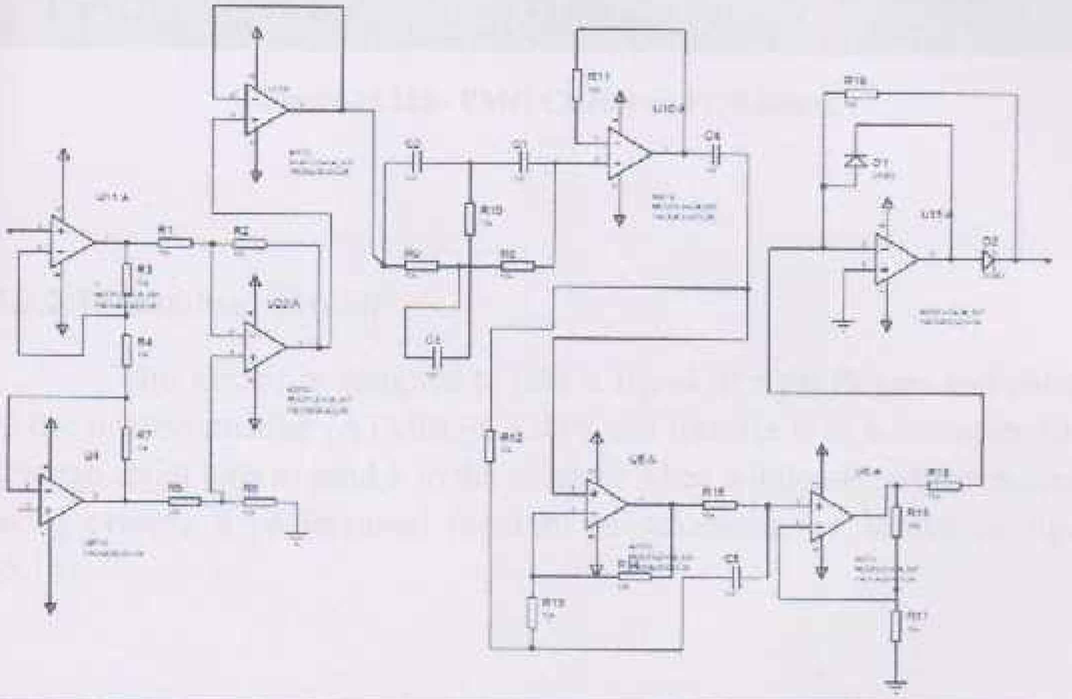

Figure (5.11):- Schematic of EMG Circuit.

And converted to PCB layout to enter it to the electronic board printed machine, as shown in figure (5.12).

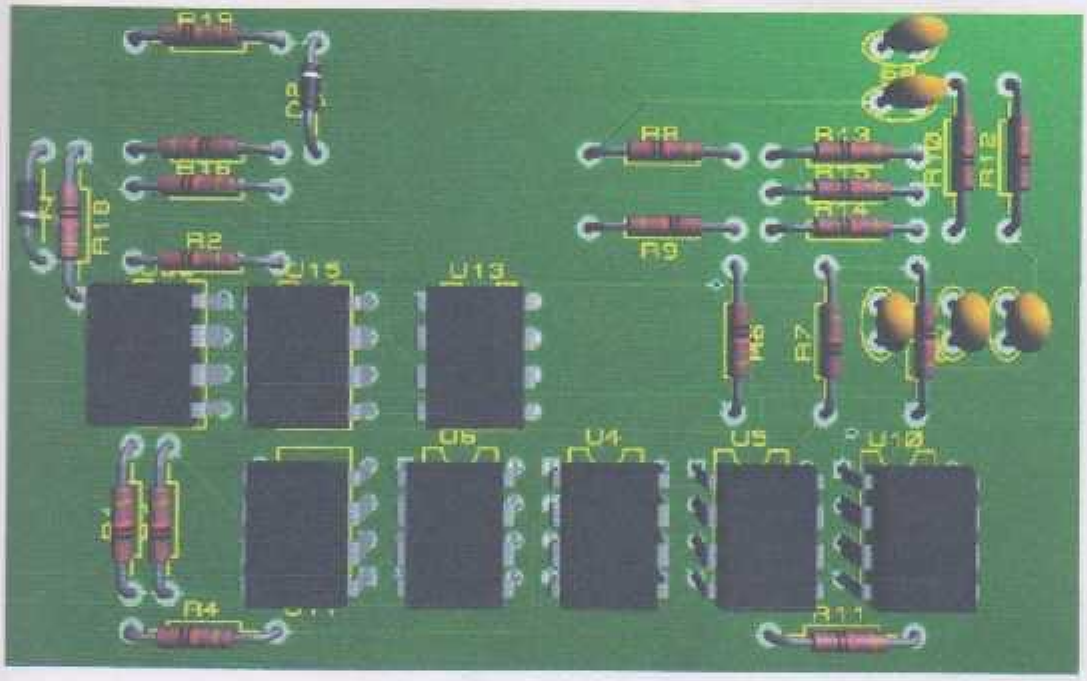

Figure (5.12):- EMG Circuit on PCB Board.

5.2.2 Transmitter Circuit

This circuit is designed to take a signal of right fingers and enter it to the microcontroller (ATMEGA 328P) and transfer it to transmitter Xbee through serial bins to send it to the receiver Xbee wirelessly, where is drawn using proteus 8 professional program as schematic, as shown in figure (5.13).

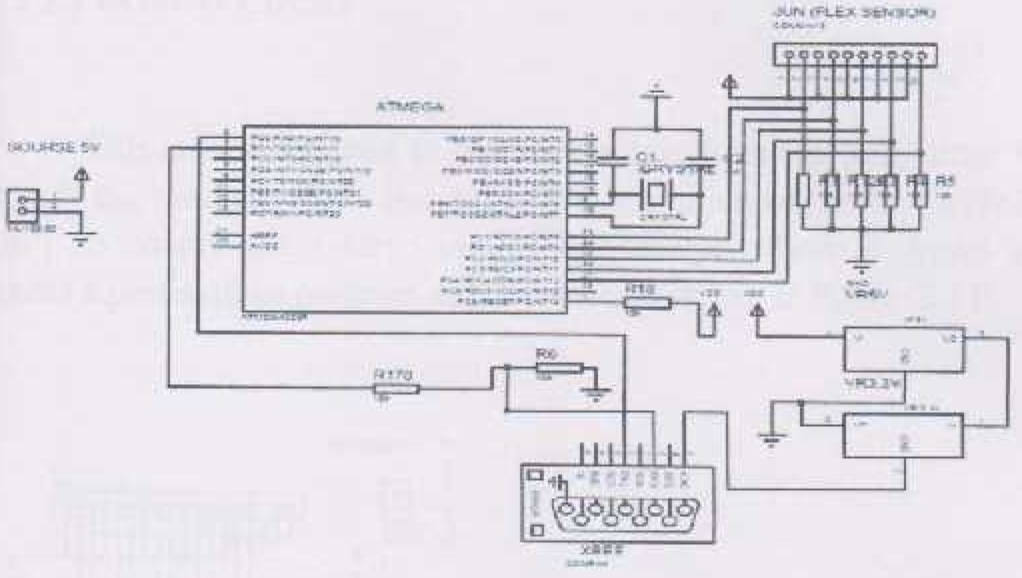

Figure (5.13):- Schematic of Transmitter Circuit.

And converted to PCB layout to enter it to the electronic board printed machine, as shown in figure (5.14).

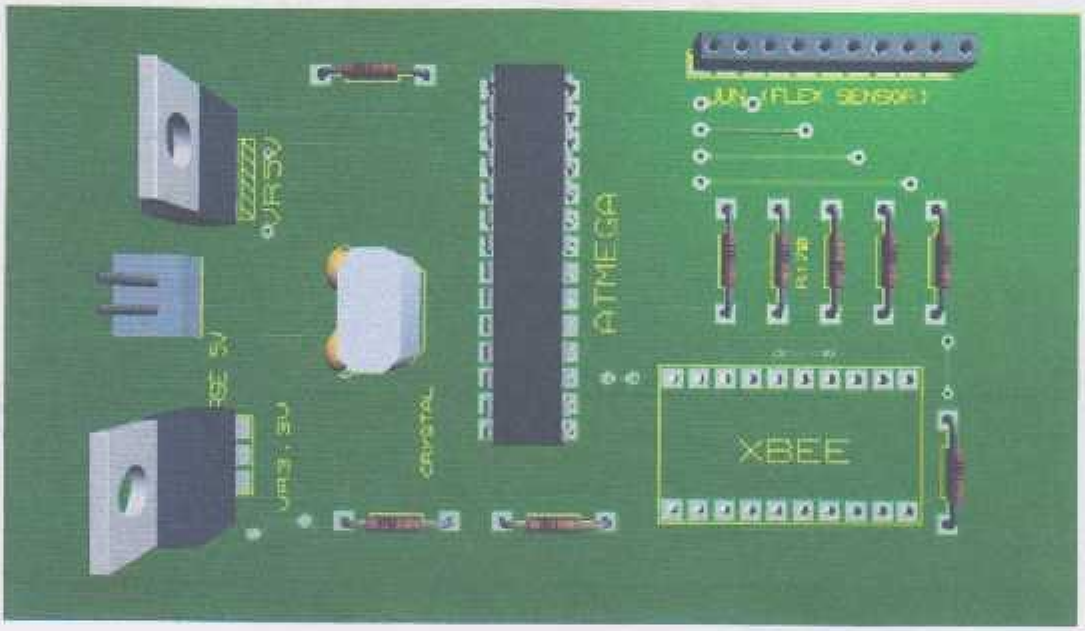

Figure (5.14):- Transmitter Circuit on PCB Board.

5.2.3 Receiver Circuit

This circuit designed to receive the text from the transmitter Xbee through the receiver Xbee and enter it to the microcontroller (ATMEGA 328P), to control the 5 servo motors movements, where is drawn using proteus 8 professional program as schematic, as shown in figure (5.15).

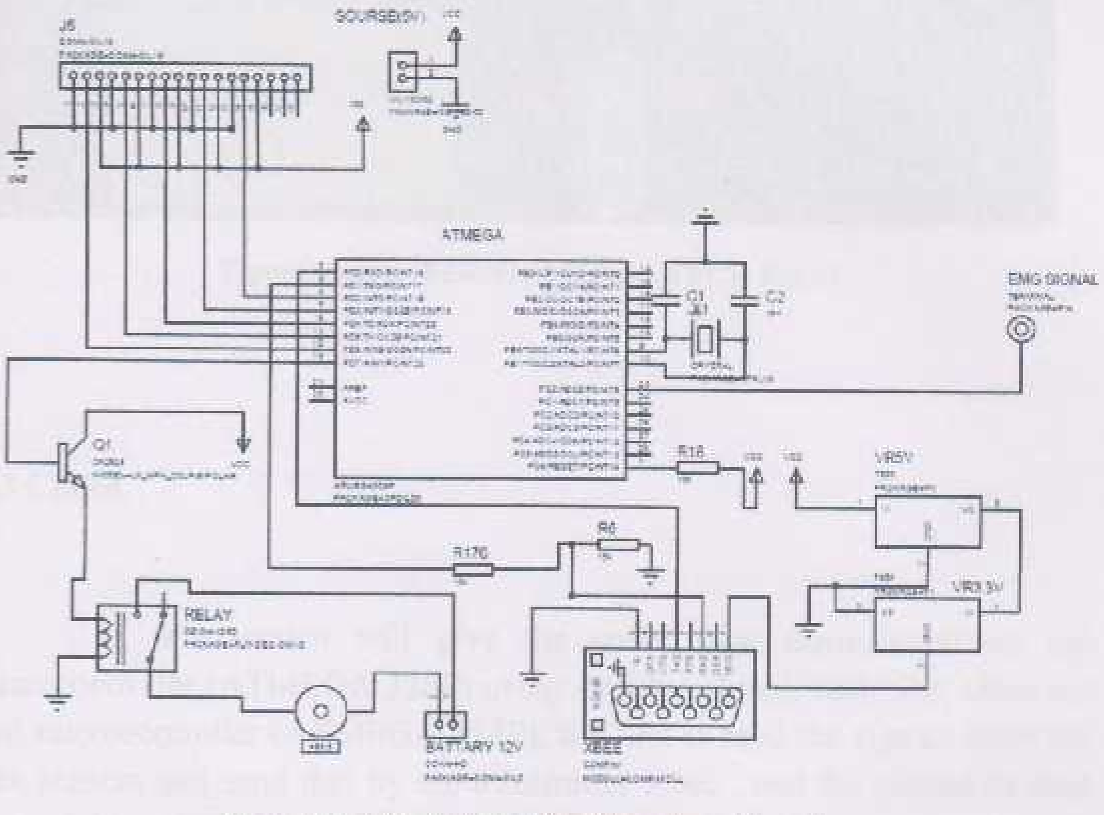

Figure (5.15):- Schematic of Receiver Circuit.

And converted to PCB layout to enter it to the electronic board printed machine, as shown in figure (5.16).

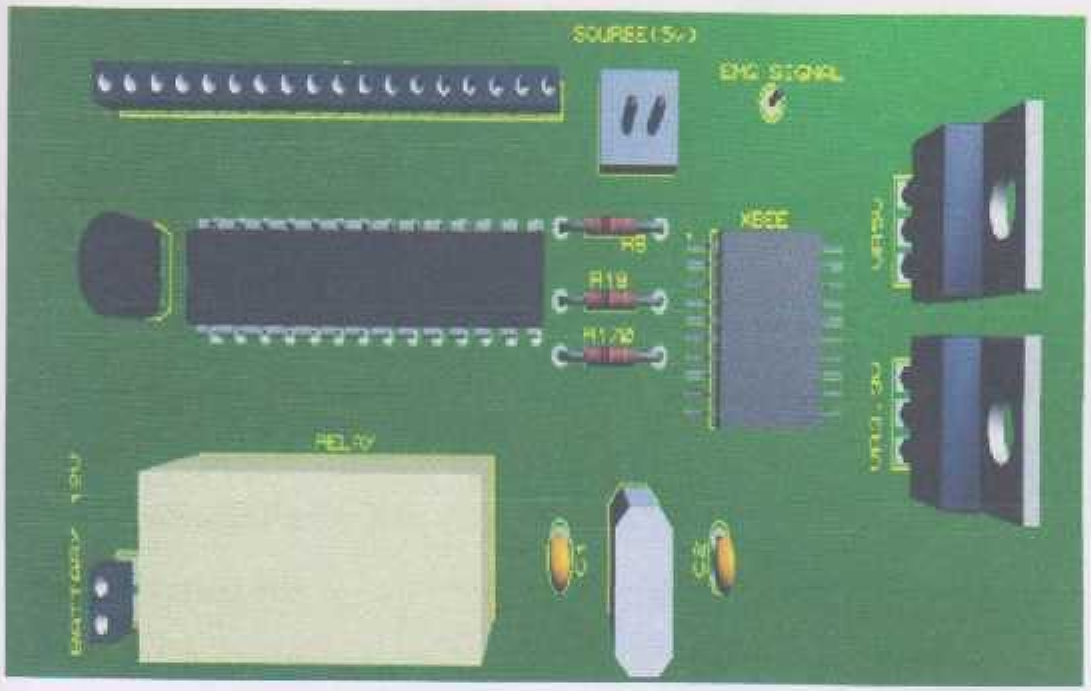

Figure (5.16):- Receiver Circuit on PCB Board.

5.3 Codes

In this section will give the codes, that downloaded on the microcontroller (ATMEGA 328P) using Arduino shield, such that; there are two microcontroller (ATMEGA 328P), the first to read the signals from the flex sensors and send that by the transmitter Xbee , and the second to read the serial text from the receiver Xbee and send orders to the servo motors.

- The code for the first ATMEGA328P :

```
const int analogInPin1 = A0;            // Analog input pin that the flex
sensors are attached to
const int analogInPin2 = A1;
const int analogInPin3 = A2;
const int analogInPin4 = A3;
const int analogInPin5 = A4;
int sensorValue1 = 0;                   // value read from the flex sensors
int sensorValue2 = 0;
int sensorValue3 = 0;
int sensorValue4 = 0;
int sensorValue5 = 0;
void setup() {
 Serial.begin(9600);          // initialize serial communications at 9600 bps:
}
void loop() {
 // read the analog in value:
 sensorValue1 = analogRead(analogInPin1);
 sensorValue2 = analogRead(analogInPin2);
 sensorValue3 = analogRead(analogInPin3);
 sensorValue4 = analogRead(analogInPin4);
```

```
sensorValue5 = analogRead(analogInPin5);
 // map it to the range of the analog out:
 sensorValue1 = map(sensorValue1, 150,340, 180, 30);      //for small sensor
sensorValue2 = map(sensorValue2, 150,340, 180, 30);
sensorValue3 = map(sensorValue3, 512,614, 0, 180); // for the large sensors
sensorValue4 = map(sensorValue4, 512,614, 0, 180);
sensorValue5 = map(sensorValue5, 512,614, 0, 180);
 // change the analog out value:
 // print the results to the serial monitor:
 Serial.print(sensorValue1);
 Serial.print("a");
  Serial.print(sensorValue2);
 Serial.print("b");
  Serial.print(sensorValue3);
 Serial.print("c");
  Serial.print(sensorValue4);
 Serial.print("d");
  Serial.print(sensorValue5);
 Serial.print("e");
 delay(10);                  // wait 10 ms
}
```

- The code for the second ATMEGA328P:-

```
#include <Servo.h>
Servo servo1;
Servo servo2;
Servo servo3;
Servo servo4;
Servo servo5;
int motorPin=8;
int analogPin=A0;
int sensorvalue=0;
void setup() {
pinMode(8,OUTPUT);
servo1.attach(2);
servo2.attach(3);
servo3.attach(4);
servo4.attach(5);
servo5.attach(6);
Serial.begin(9600);
Serial.println("Ready");
}
```

```
void loop() {
sensorvalue=analogRead(analogPin);
 if(sensorvalue>=70 & sensorvalue<=140)
 {  digitalWrite(motorPin, HIGH);
}
else
{
 digitalWrite(motorPin, LOW);
}
 static int v = 0;
 if ( Serial.available()) {
  char ch = Serial.read();
  switch(ch) {
   case '0'...'9':
    v = v * 10 + ch - '0';
    break;
   case 'a':
    servo1.write(v);
    v = 0;
    break;
```

```
case 'b':
        servo2.write(v);
        v = 0;
        break;
        case 'c':
        servo3.write(v);
        v = 0;
        break;
        case 'd':
        servo4.write(v);
        v = 0;
        break;
        case 'e':
        servo5.write(v);
        v = 0;
        break;
    }
  }
}
```

5.4 Block Diagram of the Project

The figure (5.17) illustrates the general block diagram for our project.

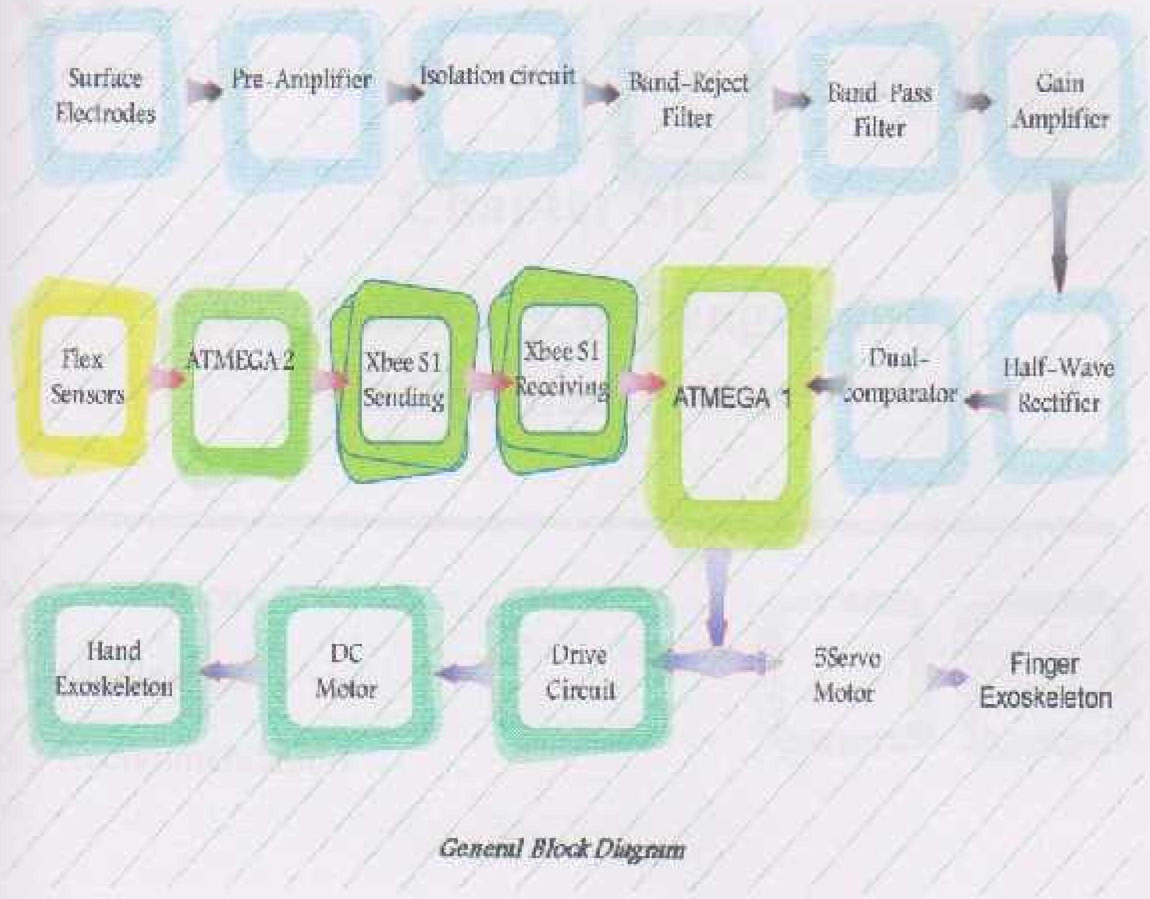

Figure (5.17):- The General Block Diagram of Project.

6

Chapter Six

Conclusions, Challenges and Recommendation

6.1 Conclusions

6.2 Challenges

6.3 Recommendation

6.1 Conclusions

1- The team extracted the muscle electrical signal through building a device that sensing the difference voltage resulting from muscle and then amplified and filtered it to aim of the ability to deal with the resultant signal.

2- The team has implemented mechanism congruence between the movement of non infected fingers and movement of infected fingers through use a flex sensors to responds with fingers movement.

3- The microcontroller was the human mind in this project, where the team has done a program to control the movement of motors based on the extracted signals.

4- The team used the ZIG BEE technology through piece called XBEE and that to send signals wirelessly to avoid block the movement of paralyzed.

5-The team used two types of motors, the first is DC motor of adequate capacity to do the hand-carry, and the second is servo motors to do the fingers movement.

6- The team designed the exoskeleton using Chemical material called polyethylene for easy formed and solidity after restructuring.

6.2 Challenges

The challenge was to extract a signals of fingers, Where that this moderation require a surgery to transplant the electrodes , that because the responsible nerve that transfer the signals to fingers non surface and could be reached only through the conduct of such operations. The solution was, the team has done to take these responsible signals to moving the fingers of the infected hand in the non infected hand using flex sensors and send the signals antenna to provide freedom of movement of the paralyzed.

6.3 Recommendation

1- An alternative to taking fingers signals from the hand self using needle electrodes recompense taking it from the fingers of the other hand.

2- An alternative to using plastic cord that tension the fingers.

3- Improving electrical muscle for people who suffer from weakness in the nervous system of gonorrhea in a certain way instead of going into the enlarged and purified and control of the weak signals.

4- Work on moving the hand in three directions instead of just moving it in two directions.

Appendix Paper

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Data sheets

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ANALOG DEVICES

Low Cost, Low Power Instrumentation Amplifier

AD620

Datasheet

ANALOG DEVICES

Low Cost, Low Power Instrumentation Amplifier

AD620

FEATURES

EASY TO USE
- Gain Set with One External Resistor (Gain Range 1 to 1000)
- Wide Power Supply Range (±2.3 V to ±18 V)
- Higher Performance than Three Op Amp IA Designs
- Available in 8-Lead DIP and SOIC Packaging
- Low Power, 1.3 mA max Supply Current

EXCELLENT DC PERFORMANCE ("B GRADE")
- 50 μV max, Input Offset Voltage
- 0.6 μV/°C max, Input Offset Drift
- 1.0 nA max, Input Bias Current
- 100 dB min Common-Mode Rejection Ratio (G = 10)

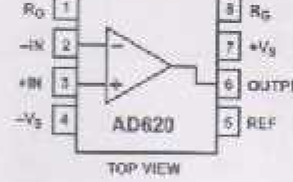
LOW NOISE
- 9 nV/√Hz, @ 1 kHz, Input Voltage Noise
- 0.28 μV p-p Noise (0.1 Hz to 10 Hz)

EXCELLENT AC SPECIFICATIONS
- 120 kHz Bandwidth (G = 100)
- 15 μs Settling Time to 0.01%

APPLICATIONS
- Weigh Scales
- ECG and Medical Instrumentation
- Transducer Interface
- Data Acquisition Systems
- Industrial Process Controls
- Battery Powered and Portable Equipment

CONNECTION DIAGRAM

8-Lead Plastic Mini-DIP (N), Cerdip (Q) and SOIC (R) Packages



PRODUCT DESCRIPTION

The AD620 is a low cost, high accuracy instrumentation amplifier that requires only one external resistor to set gains of 1 to 1000. Furthermore, the AD620 features 8-lead SOIC and DIP packaging that is smaller than discrete designs, and offers lower power (only 1.3 mA max supply current), making it a good fit for battery powered, portable (or remote) applications.

The AD620, with its high accuracy of 40 ppm maximum nonlinearity, low offset voltage of 50 μV max and offset drift of 0.6 μV/°C max, is ideal for use in precision data acquisition systems, such as weigh scales and transducer interfaces. Furthermore, the low noise, low input bias current, and low power of the AD620 make it well suited for medical applications such as ECG and noninvasive blood pressure monitors.

The low input bias current of 1.0 nA max is made possible with the use of Superβeta processing in the input stage. The AD620 works well as a preamplifier due to its low input voltage noise of 9 nV/√Hz at 1 kHz, 0.28 μV p-p in the 0.1 Hz to 10 Hz band, 0.1 pA/√Hz input current noise. Also, the AD620 is well suited for multiplexed applications with its settling time of 15 μs to 0.01% and its cost is low enough to enable designs with one in-amp per channel.

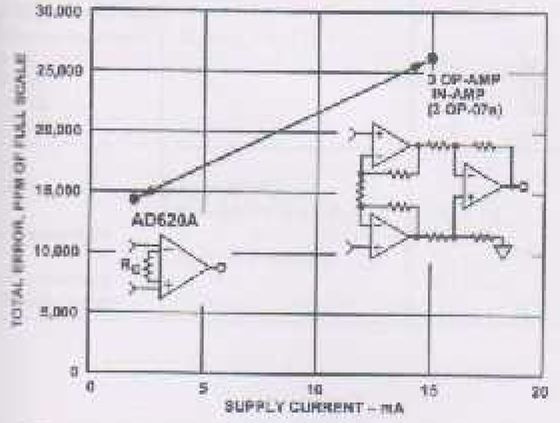


Figure 1. Three Op Amp IA Designs vs. AD620

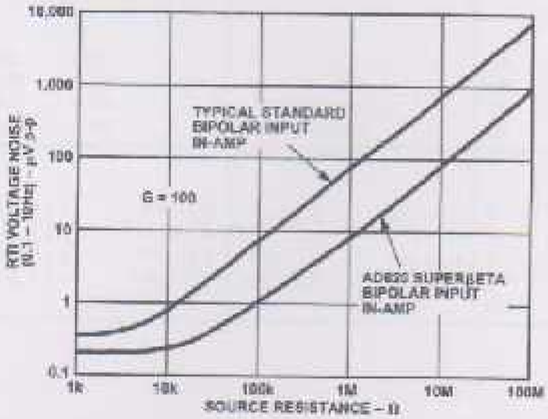


Figure 2. Total Voltage Noise vs. Source Resistance

REV. E

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781/329-4700 World Wide Web Site: http://www.analog.com
Fax: 781/326-8703

AD620–SPECIFICATIONS (Typical @ +25°C, V_S = ±15 V, and R_L = 2 kΩ, unless otherwise noted)

	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[1] Min	AD620S[1] Typ	AD620S[1] Max	Units
GAIN	G = 1 + (49.4 k/R_G)										
Gain Range		1		10,000	1		10,000	1		10,000	
Gain Error[2]	V_{OUT} = ±10 V										
G = 1			0.03	0.10		0.01	0.02		0.03	0.10	%
G = 10			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 100			0.15	0.30		0.10	0.15		0.15	0.30	%
G = 1000			0.40	0.70		0.35	0.50		0.40	0.70	%
Nonlinearity,	V_{OUT} = −10 V to +10 V,										
G = 1–1000	R_L = 10 kΩ		10	40		10	40		10	40	ppm
G = 1–100	R_L = 2 kΩ		10	95		10	95		10	95	ppm
Gain vs. Temperature											
	G = 1			10			10			10	ppm/°C
	Gain >1[2]			−50			−50			−50	ppm/°C
VOLTAGE OFFSET	(Total RTI Error = V_{OSI} + V_{OSO}/G)										
Input Offset, V_{OSI}	V_S = ±5 V to ±15 V		30	125		15	50		30	125	µV
Over Temperature	V_S = ±5 V to ±15 V			185			85			225	µV
Average TC	V_S = ±5 V to ±15 V		0.3	1.0		0.1	0.6		0.3	1.0	µV/°C
Output Offset, V_{OSO}	V_S = ±15 V		400	1000		200	500		400	1000	µV
	V_S = ±5 V			1500			750			1500	µV
Over Temperature	V_S = ±5 V to ±15 V			2000			1000			2000	µV
Average TC	V_S = ±5 V to ±15 V		5.0	15		2.5	7.0		5.0	15	µV/°C
Offset Referred to the Input vs. Supply (PSR)	V_S = ±2.3 V to ±18 V										
G = 1		80	100		80	100		80	100		dB
G = 10		95	120		100	120		95	120		dB
G = 100		110	140		120	140		110	140		dB
G = 1000		110	140		120	140		110	140		dB
INPUT CURRENT											
Input Bias Current			0.5	2.0		0.5	1.0		0.5	2	nA
Over Temperature				2.5			1.5			4	nA
Average TC			3.0			3.0			8.0		pA/°C
Input Offset Current			0.3	1.0		0.3	0.5		0.3	1.0	nA
Over Temperature				1.5			0.75			2.0	nA
Average TC			1.5			1.5			8.0		pA/°C
INPUT											
Input Impedance											
Differential			10‖2			10‖2			10‖2		GΩ‖pF
Common-Mode			10‖2			10‖2			10‖2		GΩ‖pF
Input Voltage Range[3]	V_S = ±2.3 V to ±5 V	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	$-V_S + 1.9$		$+V_S - 1.2$	V
Over Temperature		$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	$-V_S + 2.1$		$+V_S - 1.3$	V
	V_S = ±5 V to ±18 V	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	$-V_S + 1.9$		$+V_S - 1.4$	V
Over Temperature		$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.1$		$+V_S - 1.4$	$-V_S + 2.3$		$+V_S - 1.4$	V
Common-Mode Rejection Ratio DC to 60 Hz with 1 kΩ Source Imbalance	V_{CM} = 0 V to ±10 V										
G = 1		73	90		80	90		73	90		dB
G = 10		93	110		100	110		93	110		dB
G = 100		110	130		120	130		110	130		dB
G = 1000		110	130		120	130		110	130		dB
OUTPUT											
Output Swing	R_L = 10 kΩ,										
	V_S = ±2.3 V to ±5 V	$-V_S + 1.1$		$+V_S - 1.2$	$-V_S + 1.1$		$+V_S - 1.2$	$-V_S + 1.1$		$+V_S - 1.2$	V
Over Temperature		$-V_S + 1.4$		$+V_S - 1.3$	$-V_S + 1.4$		$+V_S - 1.3$	$-V_S + 1.6$		$-V_S - 1.3$	V
	V_S = ±5 V to ±18 V	$-V_S + 1.2$		$+V_S - 1.4$	$-V_S + 1.2$		$+V_S - 1.4$	$-V_S + 1.2$		$-V_S - 1.4$	V
Over Temperature		$-V_S + 1.6$		$+V_S - 1.5$	$-V_S + 1.6$		$+V_S - 1.5$	$-V_S + 2.3$		$-V_S - 1.5$	V
Short Current Circuit			±18			±18			±18		mA

…odel	Conditions	AD620A Min	AD620A Typ	AD620A Max	AD620B Min	AD620B Typ	AD620B Max	AD620S[1] Min	AD620S[1] Typ	AD620S[1] Max	Units
…NAMIC RESPONSE											
…all Signal –3 dB Bandwidth											
G = 1			1000			1000			1000		kHz
G = 10			800			800			800		kHz
G = 100			120			120			120		kHz
G = 1000			12			12			12		kHz
…ew Rate		0.75	1.2		0.75	1.2		0.75	1.2		V/µs
…ttling Time to 0.01%	10 V Step										
G = 1–100			15			15			15		µs
G = 1000			150			150			150		µs
…OISE											
…oltage Noise, 1 kHz	Total RTI Noise = $\sqrt{(e^2_{ni}) + (e_{no}/G)^2}$										
Input, Voltage Noise, e_{ni}			9	13		9	13		9	13	nV/√Hz
Output, Voltage Noise, e_{no}			72	100		72	100		72	100	nV/√Hz
RTI, 0.1 Hz to 10 Hz											
G = 1			3.0			3.0	6.0		3.0	6.0	µV p-p
G = 10			0.55			0.55	0.8		0.55	0.8	µV p-p
G = 100–1000			0.28			0.28	0.4		0.28	0.4	µV p-p
Current Noise	f = 1 kHz		100			100			100		fA/√Hz
0.1 Hz to 10 Hz			10			10			10		pA p-p
…EFERENCE INPUT											
R_{IN}			20			20			20		kΩ
I_{IN}	V_{IN+}, V_{REF} = 0		+50	+60		+50	+60		+50	+60	µA
…oltage Range		$-V_S + 1.6$		$+V_S - 1.6$	$-V_S + 1.6$		$+V_S - 1.6$	$-V_S + 1.6$		$+V_S - 1.6$	V
…in to Output			1 ± 0.0001			1 ± 0.0001			1 ± 0.0001		
…WER SUPPLY											
Operating Range[4]		±2.3		±18	±2.3		±18	±2.3		±18	V
Quiescent Current	V_S = ±2.3 V to ±18 V		0.9	1.3		0.9	1.3		0.9	1.3	mA
Over Temperature			1.1	1.6		1.1	1.6		1.1	1.6	mA
…EMPERATURE RANGE											
For Specified Performance			–40 to +85			–40 to +85			–55 to +125		°C

…OTES

…e Analog Devices military data sheet for 883B tested specifications.

…es not include effects of external resistor R_G.

…e input grounded. G = 1.

…is is defined as the same supply range which is used to specify PSR.

…ecifications subject to change without notice.

ABSOLUTE MAXIMUM RATINGS[1]

Supply Voltage . . . . ±18 V
Internal Power Dissipation[2] . . . . 650 mW
Input Voltage (Common Mode) . . . . $\pm V_S$
Differential Input Voltage . . . . ±25 V
Output Short Circuit Duration . . . . Indefinite
Storage Temperature Range (Q) . . . . –65°C to +150°C
Storage Temperature Range (N, R) . . . . –65°C to +125°C
Operating Temperature Range
AD620 (A, B) . . . . –40°C to +85°C
AD620 (S) . . . . –55°C to +125°C
Lead Temperature Range
(Soldering 10 seconds) . . . . +300°C

NOTES
[1] Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
[2] Specification is for device in free air:
8-Lead Plastic Package: θ_{JA} = 95°C/W
8-Lead Cerdip Package: θ_{JA} = 110°C/W
8-Lead SOIC Package: θ_{JA} = 155°C/W

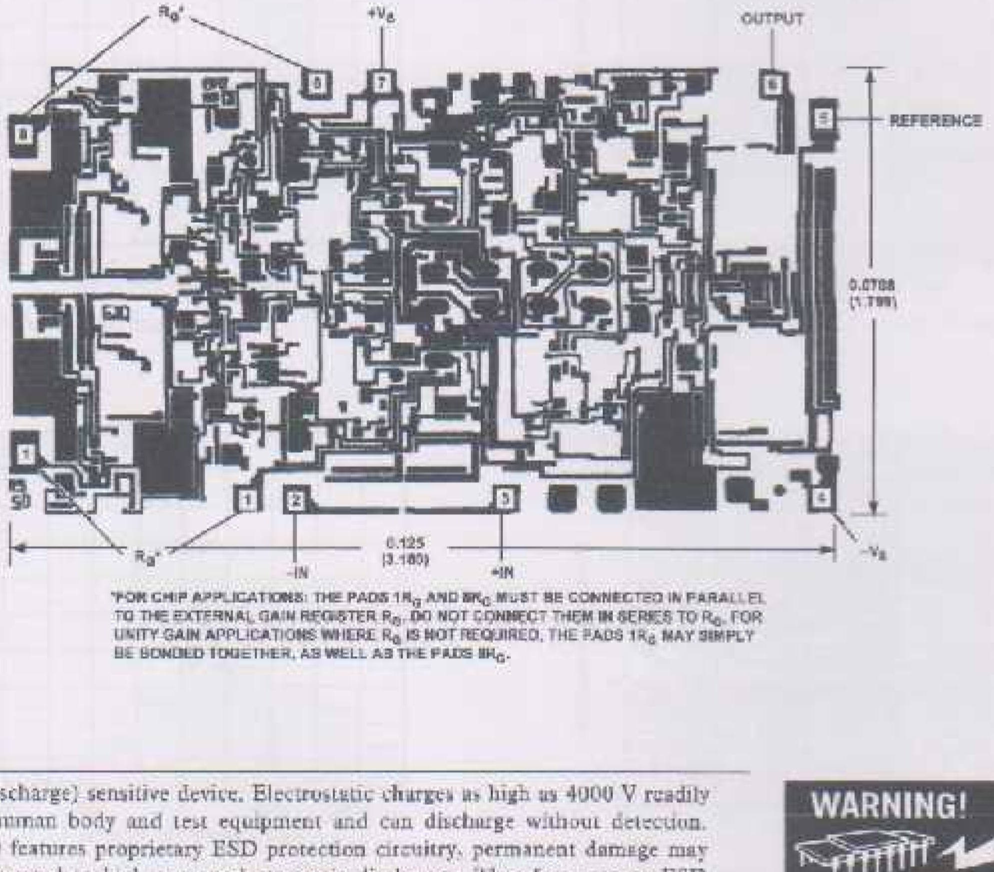
ORDERING GUIDE

Model	Temperature Ranges	Package Options*
AD620AN	–40°C to +85°C	N-8
AD620BN	–40°C to +85°C	N-8
AD620AR	–40°C to +85°C	SO-8
AD620AR-REEL	–40°C to +85°C	13" REEL
AD620AR-REEL7	–40°C to +85°C	7" REEL
AD620BR	–40°C to +85°C	SO-8
AD620BR-REEL	–40°C to +85°C	13" REEL
AD620BR-REEL7	–40°C to +85°C	7" REEL
AD620ACHIPS	–40°C to +85°C	Die Form
AD620SQ/883B	–55°C to +125°C	Q-8

*N = Plastic DIP; Q = Cerdip; SO = Small Outline.

METALIZATION PHOTOGRAPH

Dimensions shown in inches and (mm).
Contact factory for latest dimensions.



*FOR CHIP APPLICATIONS: THE PADS $1R_G$ AND $8R_G$ MUST BE CONNECTED IN PARALLEL TO THE EXTERNAL GAIN REGISTER R_G. DO NOT CONNECT THEM IN SERIES TO R_G. FOR UNITY-GAIN APPLICATIONS WHERE R_G IS NOT REQUIRED, THE PADS $1R_G$ MAY SIMPLY BE BONDED TOGETHER, AS WELL AS THE PADS $8R_G$.

CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD620 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

WARNING!
ESD SENSITIVE DEVICE

Typical Characteristics (@ +25°C, V_S = ±15 V, R_L = 2 kΩ, unless otherwise noted)

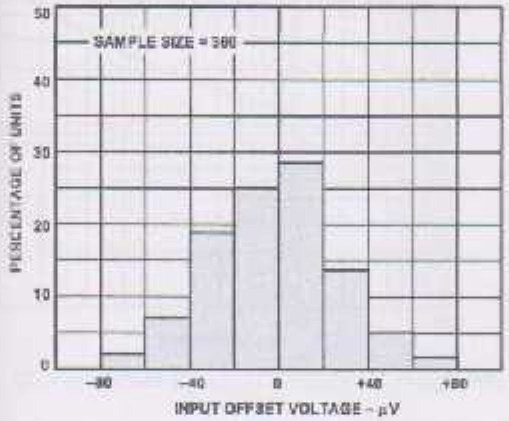


Figure 3. Typical Distribution of Input Offset Voltage

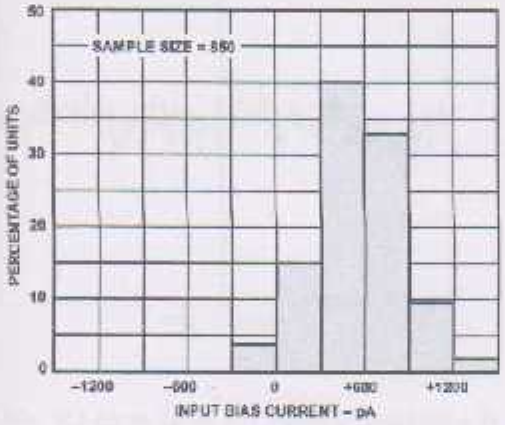


Figure 4. Typical Distribution of Input Bias Current

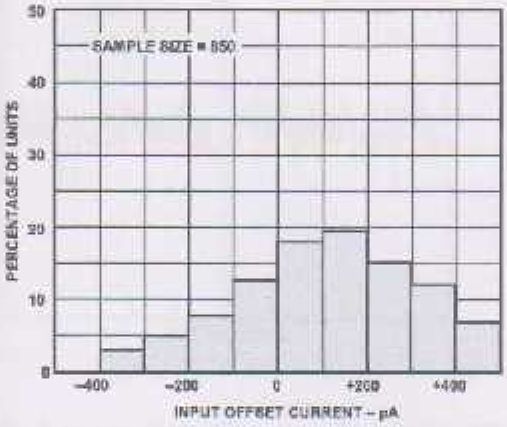


Figure 5. Typical Distribution of Input Offset Current

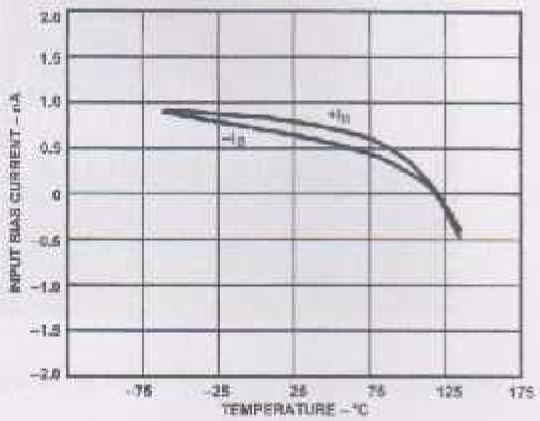


Figure 6. Input Bias Current vs. Temperature

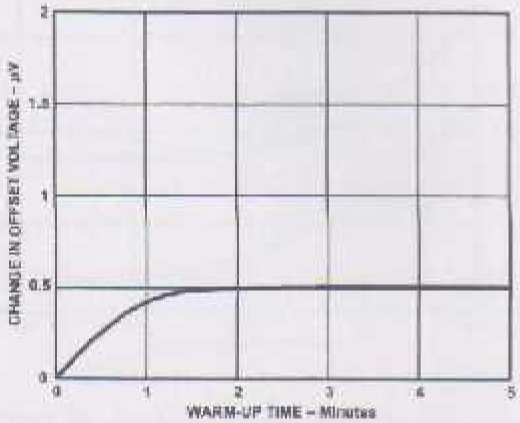


Figure 7. Change in Input Offset Voltage vs. Warm-Up Time

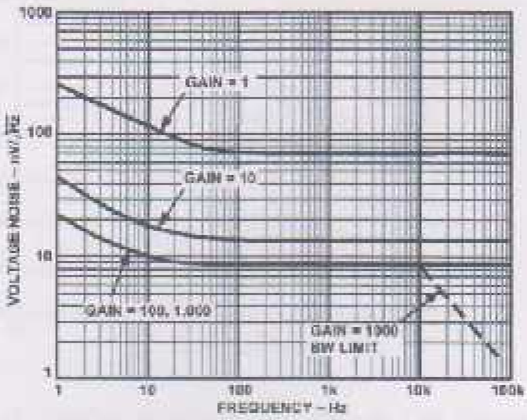


Figure 8. Voltage Noise Spectral Density vs. Frequency, (G = 1–1000)

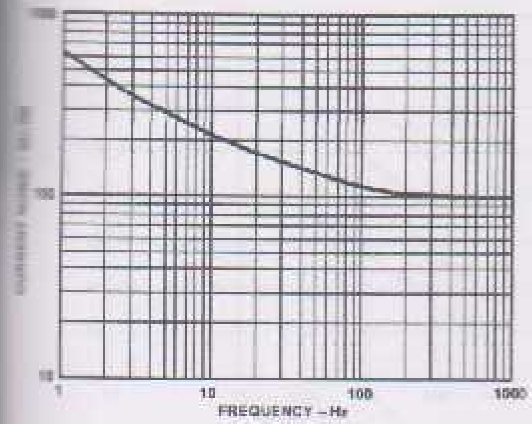


Figure 9. Current Noise Spectral Density vs. Frequency

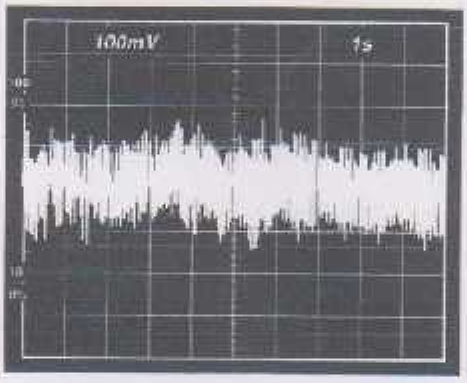


Figure 11. 0.1 Hz to 10 Hz Current Noise, 5 pA/Div

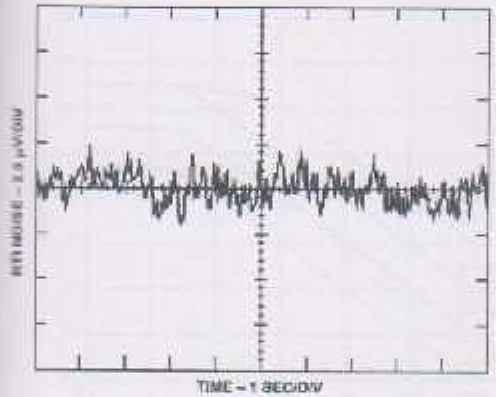


Figure 10a. 0.1 Hz to 10 Hz RTI Voltage Noise (G = 1)

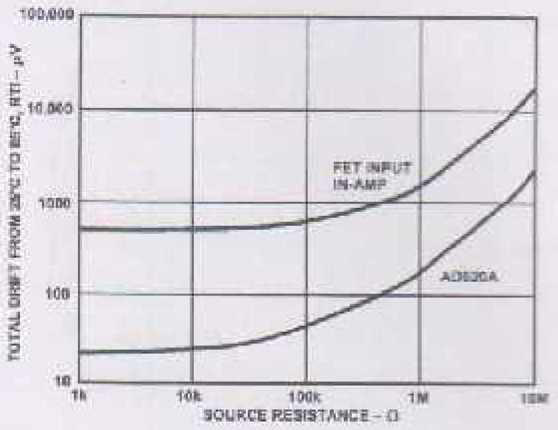


Figure 12. Total Drift vs. Source Resistance

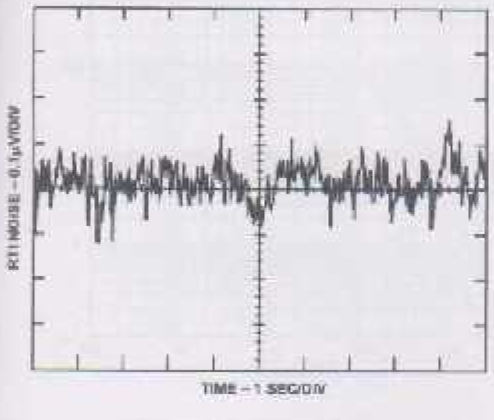


Figure 10b. 0.1 Hz to 10 Hz RTI Voltage Noise (G = 1000)

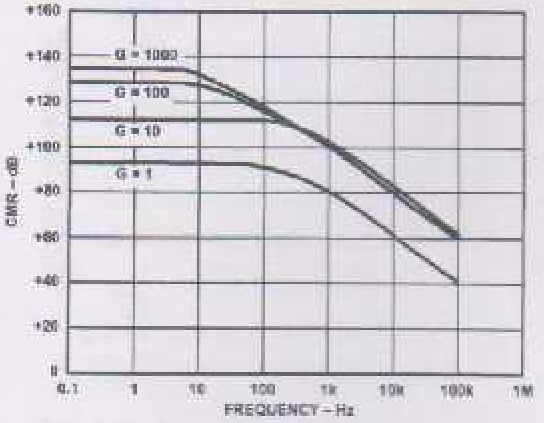


Figure 13. CMR vs. Frequency, RTI, Zero to 1 kΩ Source Imbalance

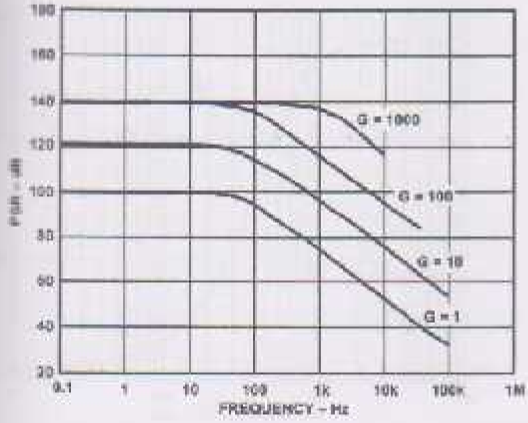


Figure 14. Positive PSR vs. Frequency, RTI (G = 1–1000)

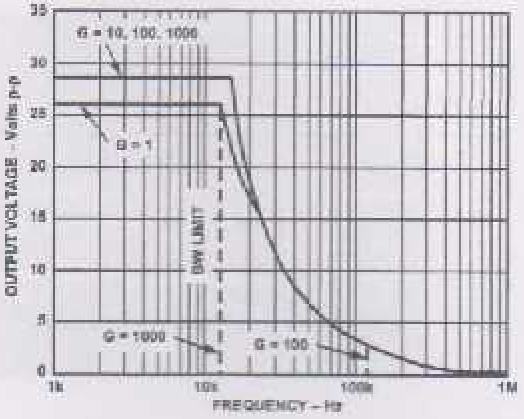


Figure 17. Large Signal Frequency Response

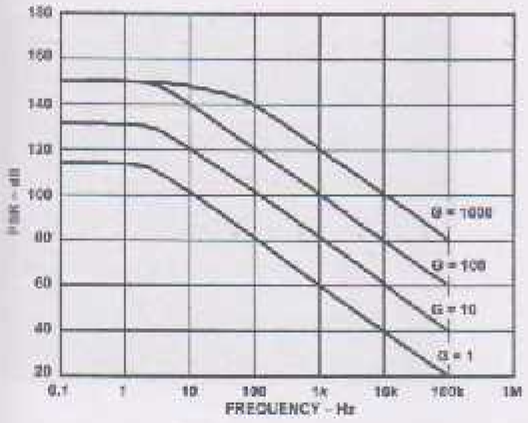


Figure 15. Negative PSR vs. Frequency, RTI (G = 1–1000)

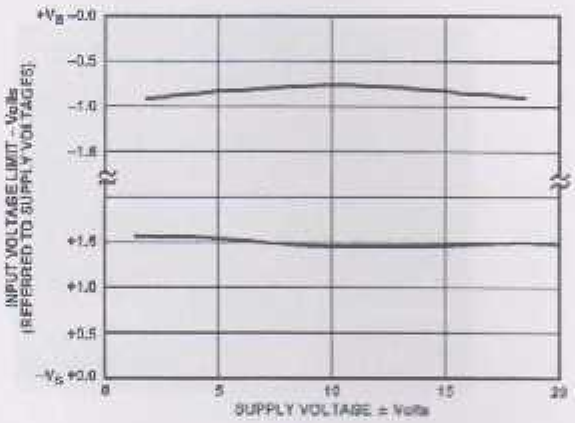


Figure 18. Input Voltage Range vs. Supply Voltage, G = 1

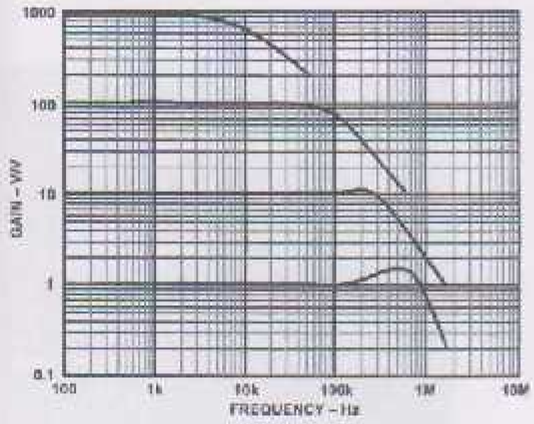


Figure 16. Gain vs. Frequency

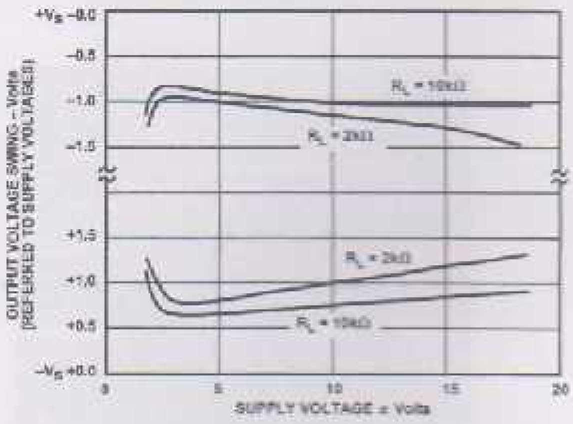


Figure 19. Output Voltage Swing vs. Supply Voltage, G = 10

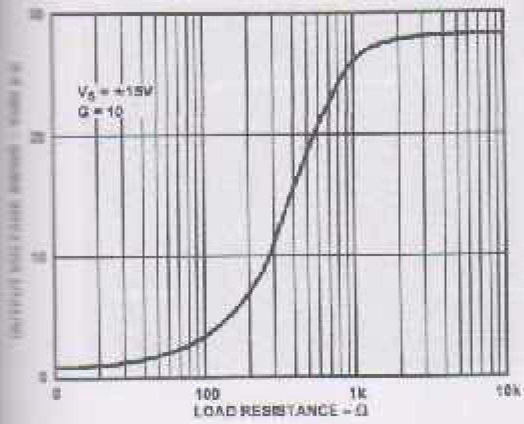


Figure 20. Output Voltage Swing vs. Load Resistance

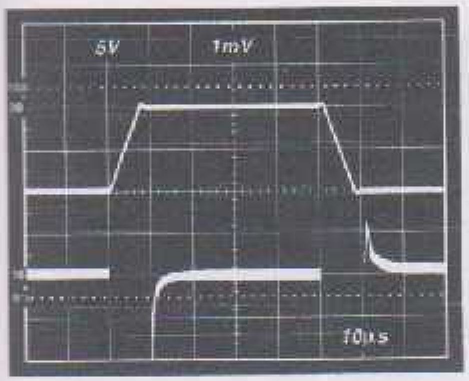


Figure 21. Large Signal Pulse Response and Settling Time (0.5 mV = 0.01%)

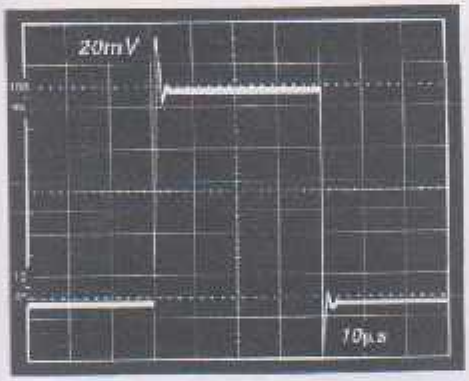


Figure 22. Small Signal Response, G = 1, R_L = 2 kΩ, C_L = 100 pF

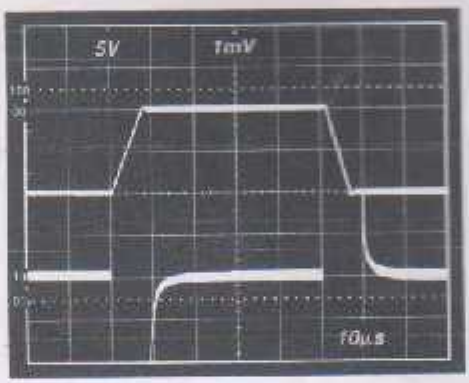


Figure 23. Large Signal Response and Settling Time, G = 10 (0.5 mV = 001%)

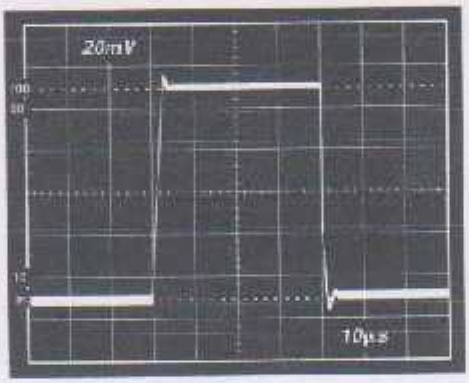


Figure 24. Small Signal Response, G = 10, R_L = 2 kΩ, C_L = 100 pF

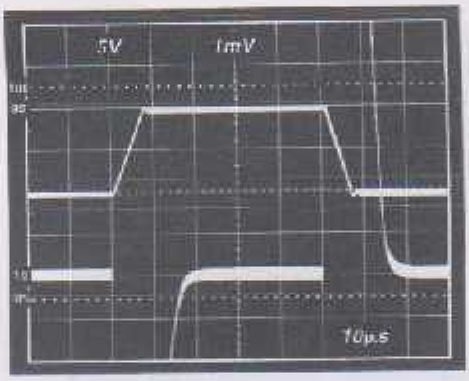


Figure 25. Large Signal Response and Settling Time, G = 100 (0.5 mV = 0.01%)

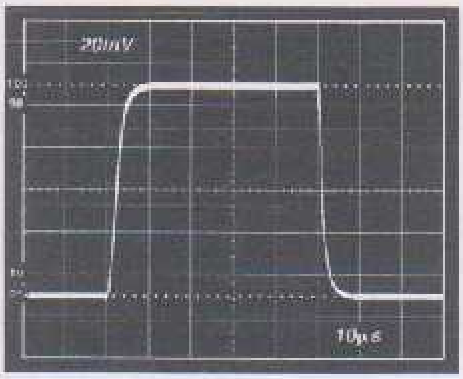


Figure 26. Small Signal Pulse Response, G = 100, R_L = 2 kΩ, C_L = 100 pF

Figure 29. Settling Time vs. Step Size (G = 1)

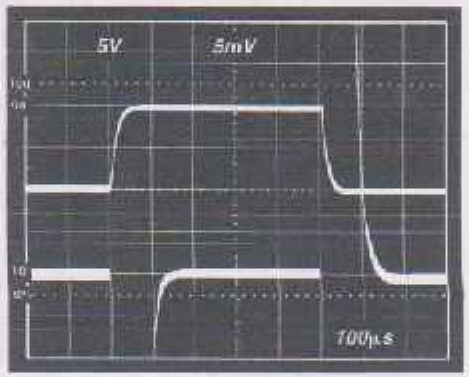


Figure 27. Large Signal Response and Settling Time, G = 1000 (0.5 mV = 0.01%)

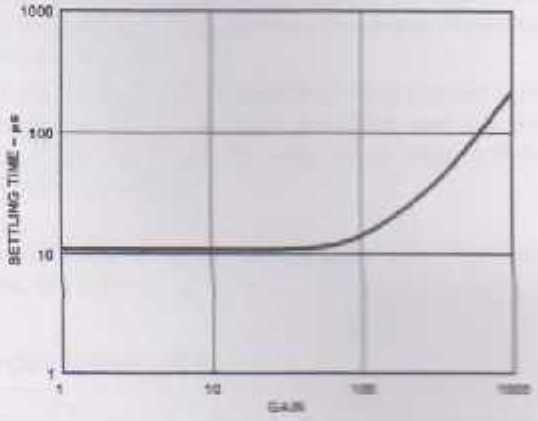


Figure 30. Settling Time to 0.01% vs. Gain, for a 10 V Step

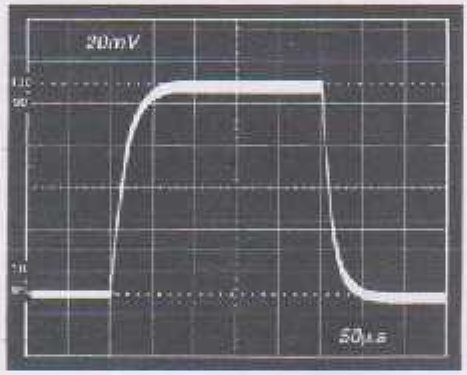


Figure 28. Small Signal Pulse Response, G = 1000, R_L = 2 kΩ, C_L = 100 pF

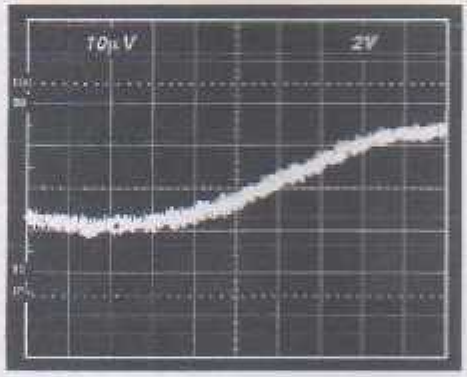
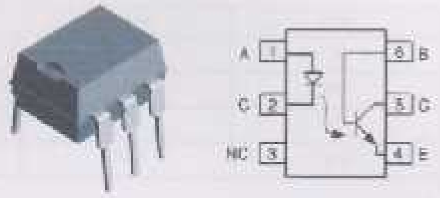


Figure 31a. Gain Nonlinearity, G = 1, R_L = 10 kΩ (10 µV = 1 ppm)

Optocoupler, Phototransistor Output, With Base Connection

Features

- Isolation Test Voltage 5300 V_{RMS}
- Interfaces with Common Logic Families
- Input-output Coupling Capacitance < 0.5 pF
- Industry Standard Dual-in-line 6-pin Package
- Lead-free component
- Component in accordance to RoHS 2002/95/EC and WEEE 2002/96/EC



Agency Approvals

- UL1577, File No. E52744 System Code H or J, Double Protection
- DIN EN 60747-5-2 (VDE0884)
  DIN EN 60747-5-5 pending
  Available with Option 1

Applications

AC Mains Detection
Reed relay driving
Switch Mode Power Supply Feedback
Telephone Ring Detection
Logic Ground Isolation
Logic Coupling with High Frequency Noise Rejection

Description

The 4N25 family is an Industry Standard Single Channel Phototransistor Coupler. This family includes the 4N25/ 4N26/ 4N27/ 4N28. Each optocoupler consists of gallium arsenide infrared LED and a silicon NPN phototransistor.

These couplers are Underwriters Laboratories (UL) listed to comply with a 5300 V_{RMS} isolation test voltage. This isolation performance is accomplished through special Vishay manufacturing process.

Compliance to DIN EN 60747-5-2(VDE0884)/ DIN EN 60747-5-5 pending partial discharge isolation specification is available by ordering option1.

These isolation processes and the Vishay ISO9001 quality program results in the highest isolation performance available for a commercial plastic phototransistor optocoupler.

The devices are also available in lead formed configuration suitable for surface mounting and are available either on tape and reel, or in standard tube shipping containers.

Note:
For additional design information see Application Note 45 Normalized Curves

Order Information

Part	Remarks
4N25	CTR > 20 %, DIP-6
4N26	CTR > 20 %, DIP-6
4N27	CTR > 10 %, DIP-6
4N28	CTR > 10 %, DIP-6
4N25-X006	CTR > 20 %, DIP-6 400 mil (option 6)
4N25-X007	CTR > 20 %, SMD-6 (option 7)
4N25-X009	CTR > 20 %, SMD-6 (option 9)
4N26-X006	CTR > 20 %, DIP-6 400 mil (option 6)
4N26-X007	CTR > 20 %, SMD-6 (option 7)
4N26-X009	CTR > 20 %, SMD-6 (option 9)
4N27-X007	CTR > 10 %, SMD-6 (option 7)
4N27-X009	CTR > 10 %, SMD-6 (option 9)
4N28-X009	CTR > 10 %, SMD-6 (option 9)

For additional information on the available options refer to Option Information.

solute Maximum Ratings

= 25 °C, unless otherwise specified
in excess of the absolute Maximum Ratings can cause permanent damage to the device. Functional operation of the device is implied at these or any other conditions in excess of those given in the operational sections of this document. Exposure to absolute Rating for extended periods of the time can adversely affect reliability.

put

Parameter	Test condition	Symbol	Value	Unit
verse voltage		V_R	5.0	V
rward current		I_F	60	mA
rge current	t < 10 µs	I_{FSM}	2.5	A
wer dissipation		P_{diss}	100	mW

tput

Parameter	Test condition	Symbol	Value	Unit
llector-emitter breakdown voltage		V_{CEO}	70	V
itter-base breakdown voltage		V_{EBO}	7.0	V
llector current		I_C	50	mA
llector current	t < 1.0 ms	I_C	100	mA
wer dissipation		P_{diss}	150	mW

upler

Parameter	Test condition	Symbol	Value	Unit
lation test voltage		V_{ISO}	5300	V_{RMS}
epage			≥ 7.0	mm
arance			≥ 7.0	mm
lation thickness between itter and detector			≥ 0.4	mm
mparative tracking index	DIN IEC 112/VDE0303, part 1		175	
lation resistance	V_{IO} = 500 V, T_{amb} = 25 °C	R_{IO}	10^{12}	Ω
	V_{IO} = 500 V, T_{amb} = 100 °C	R_{IO}	10^{11}	Ω
rage temperature		T_{stg}	- 55 to + 150	°C
erating temperature		T_{amb}	- 55 to + 100	°C
ction temperature		T_j	100	°C
ldering temperature	max.10 s, dip soldering: distance to seating plane ≥ 1.5 mm	T_{sld}	260	°C

Electrical Characteristics

T_{amb} = 25 °C, unless otherwise specified

Minimum and maximum values are testing requirements. Typical values are characteristics of the device and are the result of engineering evaluation. Typical values are for information only and are not part of the testing requirements.

Input

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Forward voltage[1]	I_F = 50 mA	V_F		1.3	1.5	V
Reverse current[1]	V_R = 3.0 V	I_R		0.1	100	µA
Capacitance	V_R = 0 V	C_O		25		pF

[1] Indicates JEDEC registered values

Output

Parameter	Test condition	Part	Symbol	Min	Typ.	Max	Unit
Collector-base breakdown voltage[1]	I_C = 100 µA		BV_{CBO}	70			V
Collector-emitter breakdown voltage[1]	I_C = 1.0 mA		BV_{CEO}	30			V
Emitter-collector breakdown voltage[1]	I_E = 100 µA		BV_{ECO}	7.0			V
I_{CEO}(dark)[1]	V_{CE} = 10 V, (base open)	4N25			5.0	50	nA
		4N26			5.0	50	nA
		4N27			5.0	50	nA
		4N28			10	100	nA
I_{CBO}(dark)[1]	V_{CB} = 10 V, (emitter open)				2.0	20	nA
Collector-emitter capacitance	V_{CE} = 0		C_{CE}		6.0		pF

[1] Indicates JEDEC registered values

Coupler

Parameter	Test condition	Part	Symbol	Min	Typ.	Max	Unit
Isolation voltage[1]	Peak, 60 Hz	4N25	V_{IO}	2500			V
		4N26	V_{IO}	1500			V
		4N27	V_{IO}	1500			V
		4N28	V_{IO}	500			V
Saturation voltage, collector-emitter	I_{CE} = 2.0 mA, I_F = 50 mA		$V_{CE(sat)}$			0.5	V
Resistance, input output[1]	V_{IO} = 500 V		R_{IO}	100			GΩ
Capacitance (input-output)	f = 1.0 MHz		C_{IO}		0.5		pF

[1] Indicates JEDEC registered values

Current Transfer Ratio

Parameter	Test condition	Part	Symbol	Min	Typ.	Max	Unit
DC Current Transfer Ratio[1]	V_{CE} = 10 V, I_F = 10 mA	4N25	CTR_{DC}	20	50		%
		4N26	CTR_{DC}	20	50		%
		4N27	CTR_{DC}	10	30		%
		4N28	CTR_{DC}	10	30		%

[1] Indicates JEDEC registered value

Switching Characteristics

Parameter	Test condition	Symbol	Min	Typ.	Max	Unit
Rise and fall times	V_{CE} = 10 V, I_F = 10 mA, R_L = 100 Ω	t_r, t_f		2.0		µs

Typical Characteristics (Tamb = 25 °C unless otherwise specified)

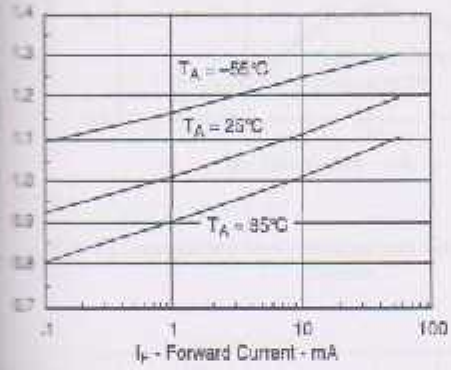


Figure 1. Forward Voltage vs. Forward Current

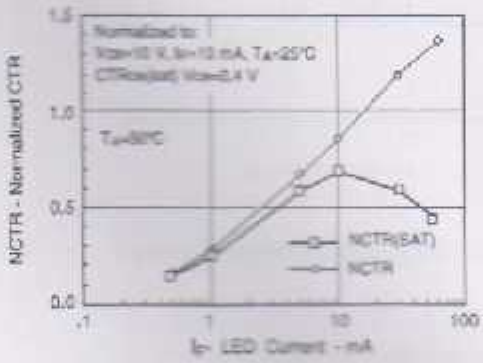


Figure 3. Normalized Non-saturated and Saturated CTR vs. LED Current

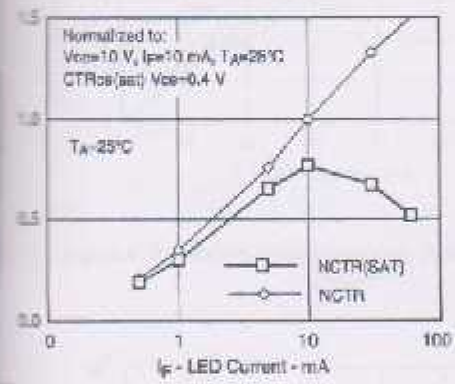


Figure 2. Normalized Non-Saturated and Saturated CTR vs. LED Current

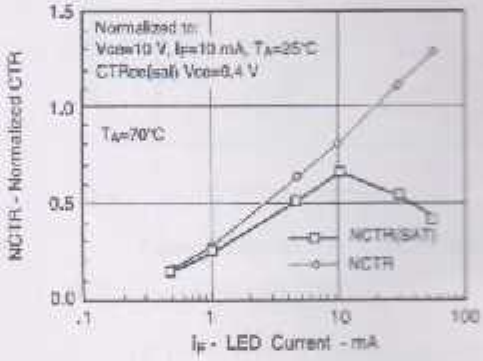


Figure 4. Normalized Non-saturated and saturated CTR vs. LED Current

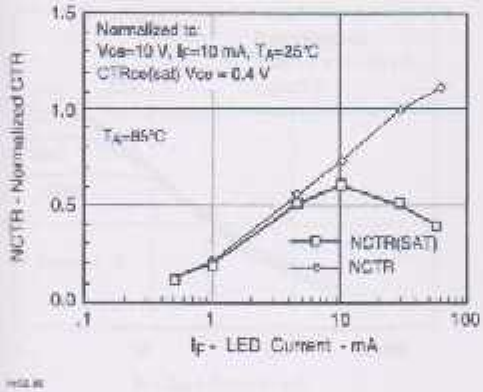


Figure 5. Normalized Non-saturated and saturated CTR vs. LED Current

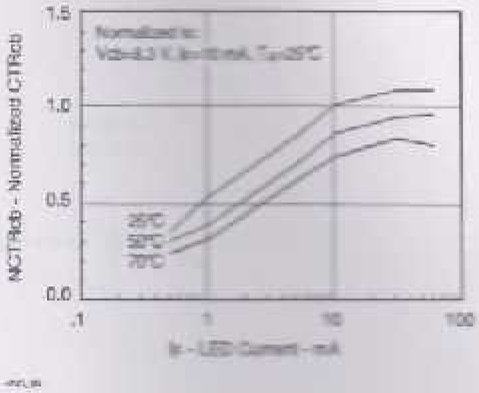


Figure 8. Normalized CTRcb vs. LED Current and Temp.

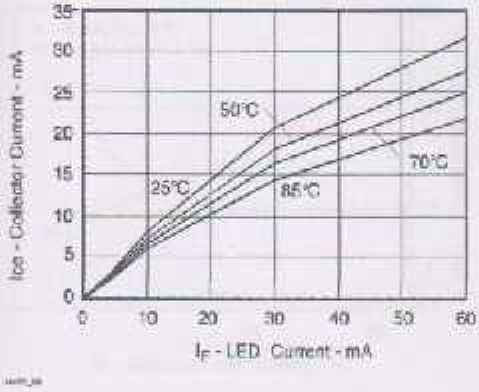


Figure 6. Collector-Emitter Current vs. Temperature and LED Current

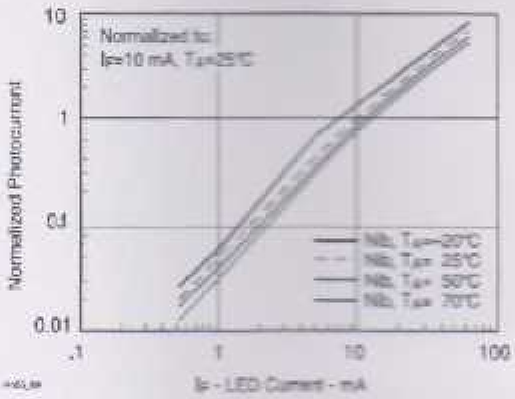


Figure 9. Normalized Photocurrent vs. IF and Temp.

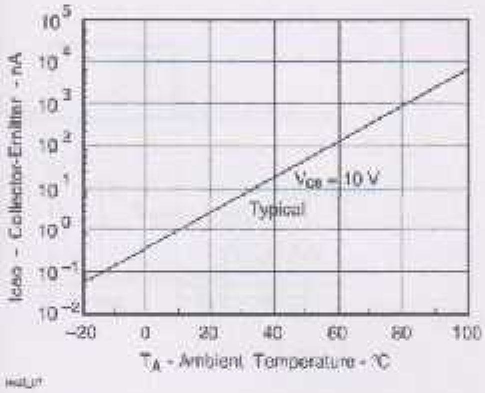


Figure 7. Collector-Emitter Leakage Current vs.Temp.

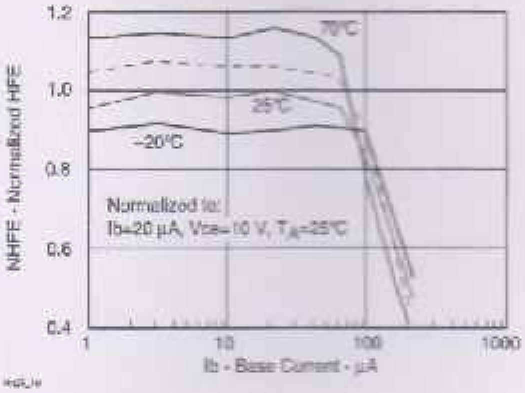


Figure 10. Normalized Non-saturated HFE vs. Base Current and Temperature

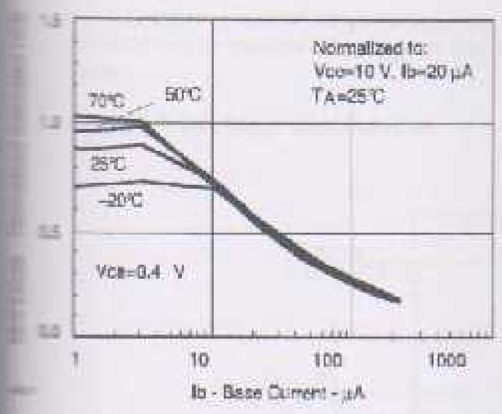


Figure 11. Normalized HFE vs. Base Current and Temp.

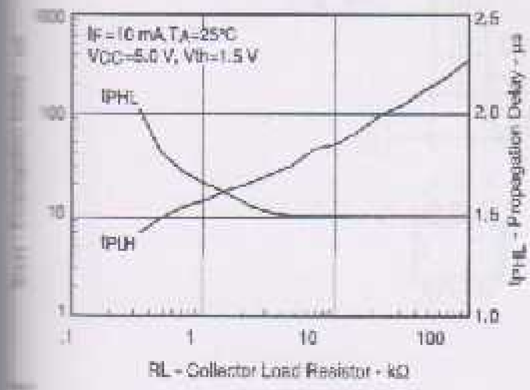


Figure 12. Propagation Delay vs. Collector Load Resistor

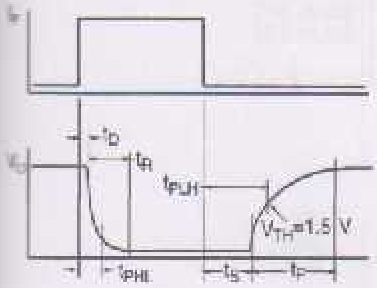


Figure 13. Switching Timing

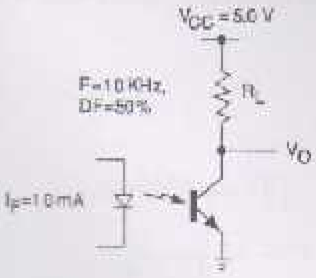
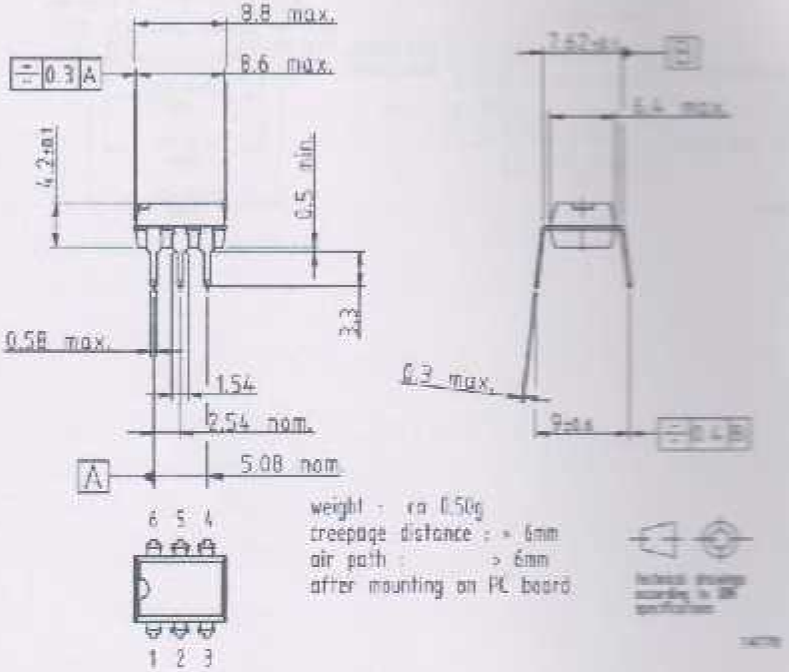


Figure 14. Switching Schematic

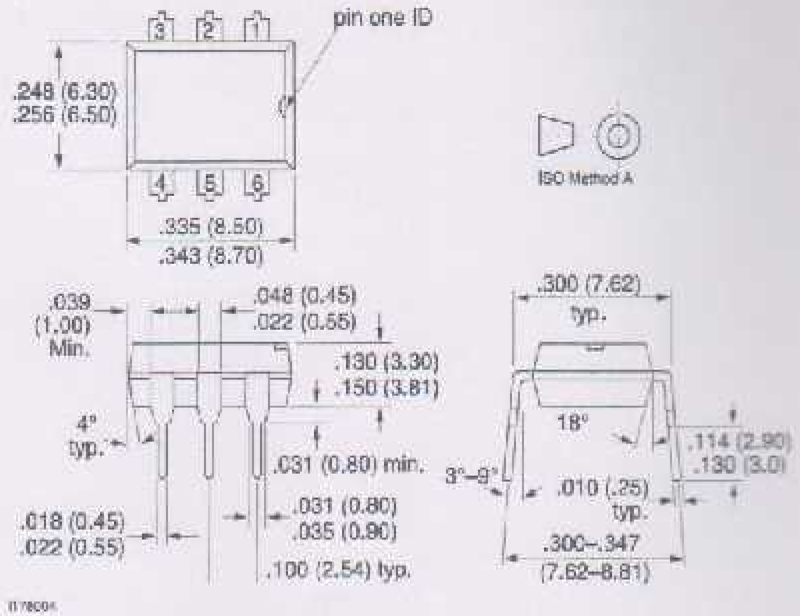
Package Dimensions in Inches (mm)

For 4N25/26/27..... see DIL300-6 Package dimension in the Package Section.
For 4N28 and for products with an option designator (e.g. 4N25-X001 or 4N26-X007)..... see DIP-6 Package dimensions in the Package Section.

DIL300-6 Package Dimensions

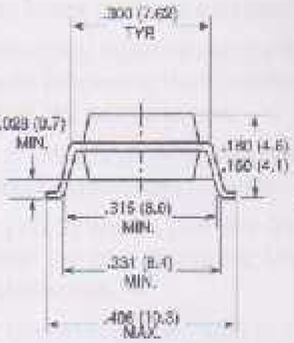


DIP-6 Package Dimensions

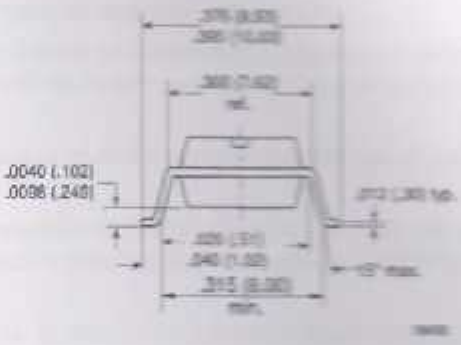


Option 6

Option 7



Option 9



Ozone Depleting Substances Policy Statement

It is the policy of Vishay Semiconductor GmbH to

1. Meet all present and future national and international statutory requirements.
2. Regularly and continuously improve the performance of our products, processes, distribution and operatingsystems with respect to their impact on the health and safety of our employees and the public, as well as their impact on the environment.

It is particular concern to control or eliminate releases of those substances into the atmosphere which are known as ozone depleting substances (ODSs).

The Montreal Protocol (1987) and its London Amendments (1990) intend to severely restrict the use of ODSs and forbid their use within the next ten years. Various national and international initiatives are pressing for an earlier ban on these substances.

Vishay Semiconductor GmbH has been able to use its policy of continuous improvements to eliminate the use of ODSs listed in the following documents.

1. Annex A, B and list of transitional substances of the Montreal Protocol and the London Amendments respectively
2. Class I and II ozone depleting substances in the Clean Air Act Amendments of 1990 by the Environmental Protection Agency (EPA) in the USA
3. Council Decision 88/540/EEC and 91/690/EEC Annex A, B and C (transitional substances) respectively.

Vishay Semiconductor GmbH can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

We reserve the right to make changes to improve technical design
and may do so without further notice.
Parameters can vary in different applications. All operating parameters must be validated for each customer application by the customer. Should the buyer use Vishay Semiconductors products for any unintended or unauthorized application, the buyer shall indemnify Vishay Semiconductors against all claims, costs, damages, and expenses, arising out of, directly or indirectly, any claim of personal damage, injury or death associated with such unintended or unauthorized use.

Vishay Semiconductor GmbH, P.O.B. 3535, D-74025 Heilbronn, Germany
Telephone: 49 (0)7131 67 2831, Fax number: 49 (0)7131 67 2423

LM741

Single Operational Amplifier

Features

- Short circuit protection
- Excellent temperature stability
- Internal frequency compensation
- High Input voltage range
- Null of offset

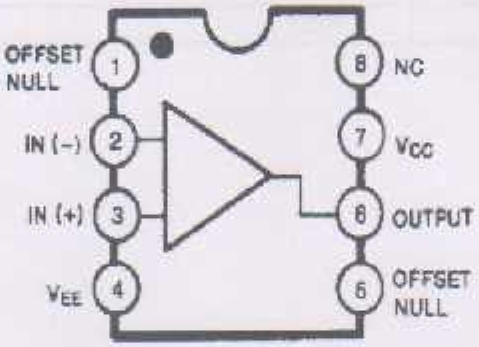
Description

The LM741 series are general purpose operational amplifiers. It is intended for a wide range of analog applications. The high gain and wide range of operating voltage provide superior performance in integrator, summing amplifier, and general feedback applications.

8-DIP

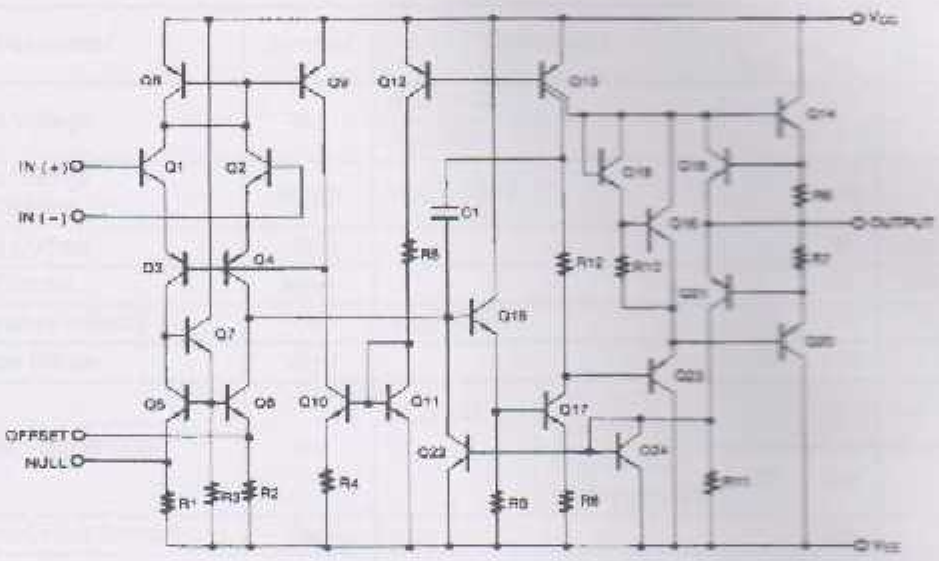
8-SOP

Internal Block Diagram



Rev. 1.0.1

Schematic Diagram



Absolute Maximum Ratings (TA = 25°C)

Parameter	Symbol	Value	Unit
Supply Voltage	VCC	±18	V
Differential Input Voltage	VI(DIFF)	30	V
Input Voltage	VI	±15	V
Output Short Circuit Duration	-	Indefinite	-
Power Dissipation	PD	500	mW
Operating Temperature Range LM741C LM741I	TOPR	0 ~ + 70 -40 ~ +85	°C
Storage Temperature Range	TSTG	-65 ~ + 150	°C

Electrical Characteristics

(V_{CC} = 15V, V_{EE} = - 15V, T_A = 25 °C, unless otherwise specified)

Parameter		Symbol	Conditions		LM741C/LM741I Min.	Typ.	Max.	Unit
Input Offset Voltage		V_{IO}	$R_S \le 10K\Omega$		-	2.0	6.0	mV
			$R_S \le 50\Omega$		-	-	-	
Input Offset Voltage Adjustment Range		$V_{IO(R)}$	V_{CC} = ±20V		-	±15	-	mV
Input Offset Current		I_{IO}	-		-	20	200	nA
Input Bias Current		I_{BIAS}	-		-	80	500	nA
Input Resistance (Note1)		R_I	V_{CC} =±20V		0.3	2.0	-	MΩ
Input Voltage Range		$V_{I(R)}$	-		±12	±13	-	V
Large Signal Voltage Gain		G_V	$R_L \ge 2K\Omega$	V_{CC} =±20V, $V_{O(P-P)}$ =±15V	-	-	-	V/mV
				V_{CC} =±15V, $V_{O(P-P)}$ =±10V	20	200	-	
Output Short Circuit Current		I_{SC}	-		-	25	-	mA
Output Voltage Swing		$V_{O(P-P)}$	V_{CC} = ±20V	$R_L \ge 10K\Omega$	-	-	-	V
				$R_L \ge 2K\Omega$	-	-	-	
			V_{CC} = ±15V	$R_L \ge 10K\Omega$	±12	±14	-	
				$R_L \ge 2K\Omega$	±10	±13	-	
Common Mode Rejection Ratio		CMRR	$R_S \le 10K\Omega$, V_{CM} = ±12V		70	90	-	dB
			$R_S \le 50\Omega$, V_{CM} = ±12V		-	-	-	
Power Supply Rejection Ratio		PSRR	V_{CC} = ±15V to V_{CC} = ±15V $R_S \le 50\Omega$		-	-	-	dB
			V_{CC} = ±15V to V_{CC} = ±15V $R_S \le 10K\Omega$		77	96	-	
Transient Response	Rise Time	T_R	Unity Gain		-	0.3	-	μs
	Overshoot	OS			-	10	-	%
Bandwidth		BW	-		-	-	-	MHz
Slew Rate		SR	Unity Gain		-	0.5	-	V/μs
Supply Current		I_{CC}	R_L= ∞Ω		-	1.5	2.8	mA
Power Consumption		P_C	V_{CC} = ±20V		-	-	-	mW
			V_{CC} = ±15V		-	50	85	

Note:
1. Guaranteed by design.

Electrical Characteristics

(0°C ≤ T_A ≤ 70 °C V_{CC} = ±15V, unless otherwise specified)
The following specification apply over the range of 0°C ≤ T_A ≤ +70 °C for the LM741C; and the -40°C ≤ T_A ≤ +85 °C for the LM741I

Parameter	Symbol	Conditions		LM741C/LM741I Min.	LM741C/LM741I Typ.	LM741C/LM741I Max.	Unit
Input Offset Voltage	V_{IO}	R_S≤50Ω		-	-	-	mV
		R_S≤10KΩ		-	-	7.5	
Input Offset Voltage Drift	$\Delta V_{IO}/\Delta T$	-		-	-		μV/°C
Input Offset Current	I_{IO}	-		-	-	300	nA
Input Offset Current Drift	$\Delta I_{IO}/\Delta T$	-		-	-		nA/°C
Input Bias Current	I_{BIAS}	-		-	-	0.8	μA
Input Resistance (Note1)	R_I	V_{CC} = ±20V		-	-	-	MΩ
Input Voltage Range	$V_{I(R)}$	-		±12	±13	-	V
Output Voltage Swing	$V_{O(P-P)}$	V_{CC} =±20V	R_S≥10KΩ	-	-	-	V
			R_S≥2KΩ	-	-	-	
		V_{CC} =±15V	R_S≥10KΩ	±12	±14	-	
			R_S≥2KΩ	±10	±13	-	
Output Short Circuit Current	I_{SC}	-		10	-	40	mA
Common Mode Rejection Ratio	CMRR	R_S≤10KΩ, V_{CM} = ±12V		70	90	-	dB
		R_S≤50Ω, V_{CM} = ±12V		-	-	-	
Power Supply Rejection Ratio	PSRR	V_{CC} = ±20V to ±5V	R_S≤50Ω	-	-	-	dB
			R_S≤10KΩ	77	96	-	
Large Signal Voltage Gain	G_V	R_S≥2KΩ	V_{CC} = ±20V, $V_{O(P-P)}$ = ±15V	-	-	-	V/mV
			V_{CC} = ±15V, $V_{O(P-P)}$ = ±10V	15	-	-	
			V_{CC} = ±15V, $V_{O(P-P)}$ = ±2V	-	-	-	

Note :
1. Guaranteed by design.

Typical Performance Characteristics

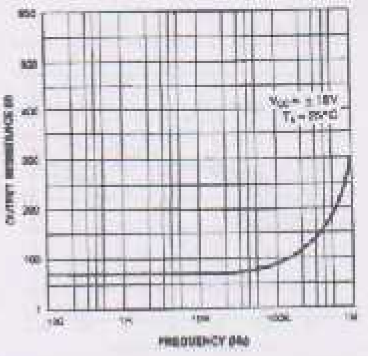


Figure 1. Output Resistance vs Frequency

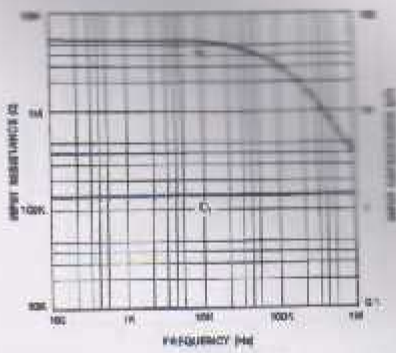


Figure 2. Input Resistance and Input Capacitance vs Frequency

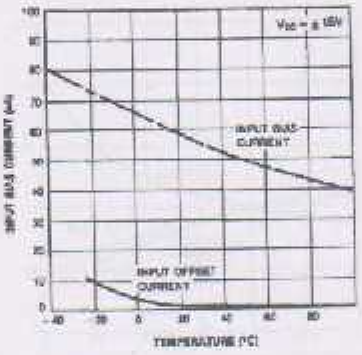


Figure 3. Input Bias Current vs Ambient Temperature

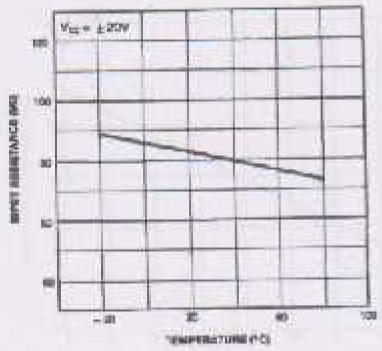


Figure 4. Power Consumption vs Ambient Temperature

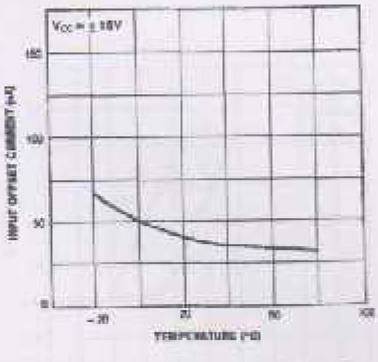


Figure 5. Input Offset Current vs Ambient Temperature

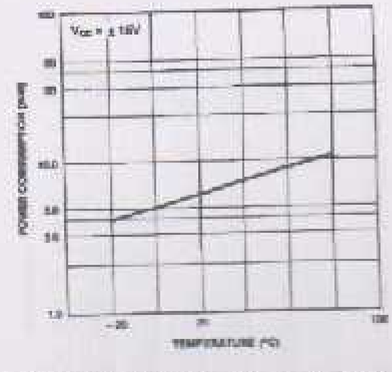


Figure 6. Input Resistance vs Ambient Temperature

Typical Performance Characteristics (continued)

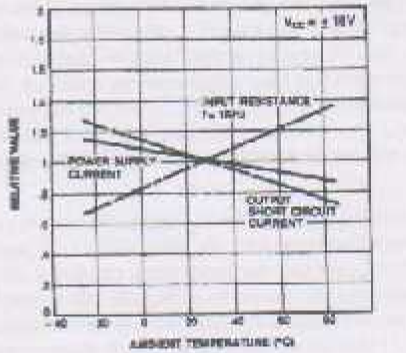


Figure 7. Normalized DC Parameters vs Ambient Temperature

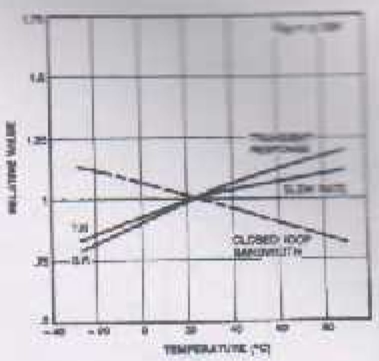


Figure 8. Frequency Characteristics vs Ambient Temperature

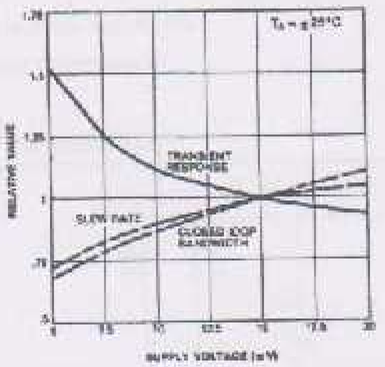


Figure 9. Frequency Characteristics vs Supply Voltage

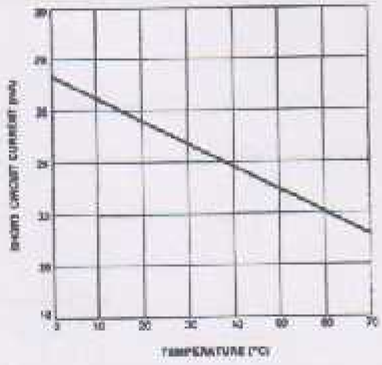
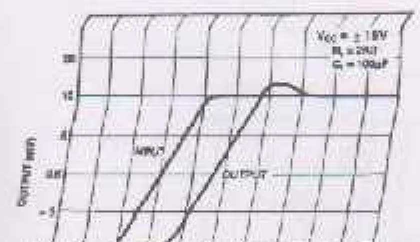
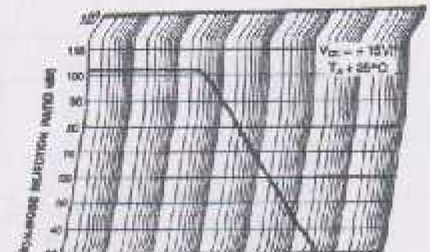


Figure 10. Output Short Circuit Current vs Ambient Temperature





Dual voltage comparator

DESCRIPTION

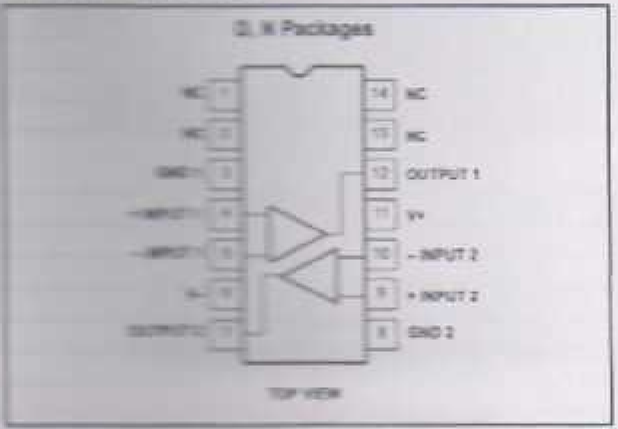
The LM319 series are precision high-speed dual comparators fabricated on a single monolithic chip. They are designed to operate over a wide range of supply voltages down to a single 5V logic supply and ground. Further, they have higher gain and lower input currents than devices like the μA710. The uncommitted collector of the output stage makes the LM319 compatible with RTL, DTL, and TTL as well as capable of driving lamps and relays at currents up to 25mA.

Although designed primarily for applications requiring operation from digital logic supplies, the LM319 series are fully specified for power supplies up to ±15V. It features faster response than the LM111 at the expense of higher power dissipation. However, the high-speed, wide operating voltage range and low package count make the LM319 much more versatile than older devices like the μA711.

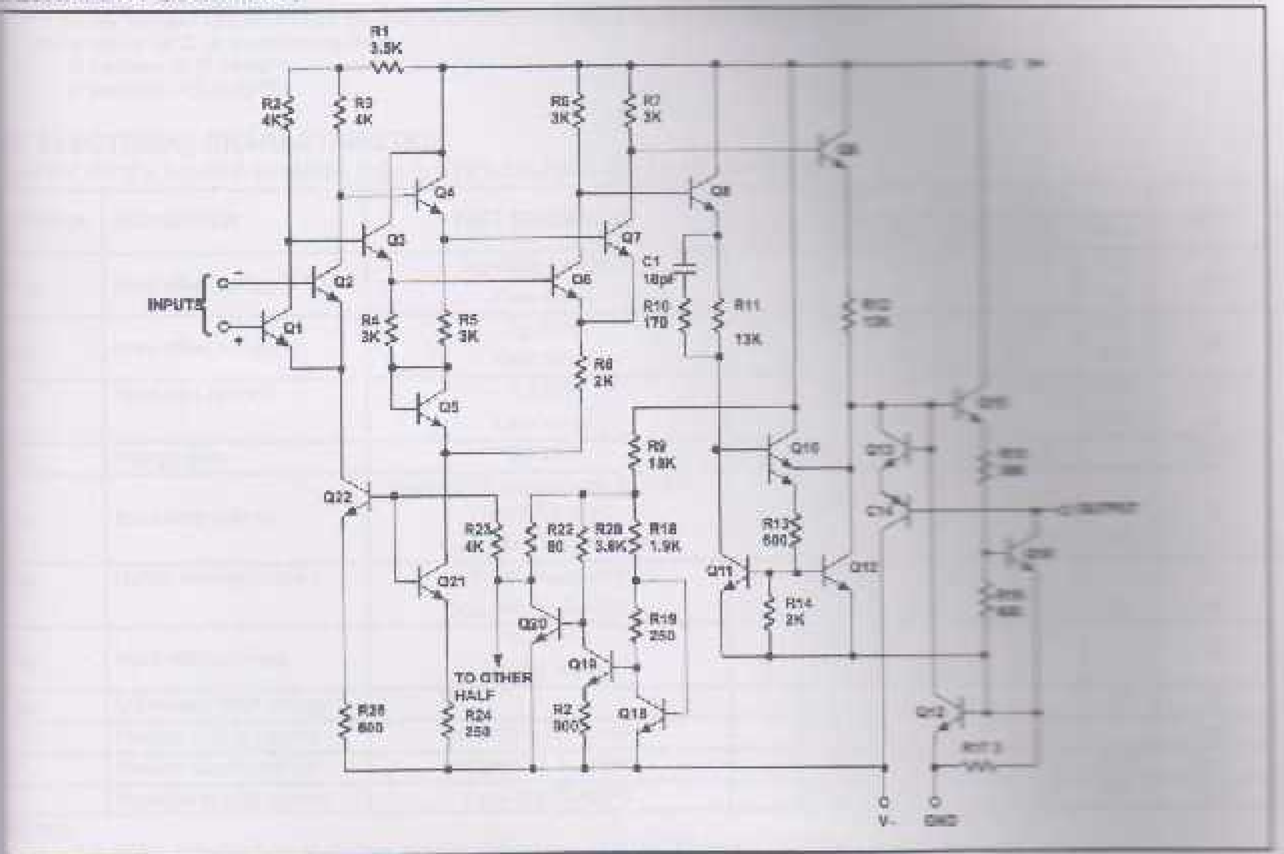
FEATURES

- Two independent comparators
- Operates from a single 5V supply
- Typically 80ns response time at ±15V
- Minimum fanout of 3 (each side)
- Maximum input current of 1μA over temperature
- Inputs and outputs can be isolated from system ground
- High common-mode slew rate

PIN CONFIGURATION



EQUIVALENT SCHEMATIC



ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	DWG #
14-Pin Plastic Small Outline (SO) Package	-25 to +85°C	LM219D	0175D
14-Pin Plastic Small Outline (SO) Package	0 to +70°C	LM319D	0175D
14-Pin Plastic Dual In-Line Package (DIP)	0 to +70°C	LM319N	0405B

ABSOLUTE MAXIMUM RATINGS

SYMBOL	PARAMETER	RATING	UNIT
V_S	Total supply voltage	36	V
	Output to negative supply voltage	36	V
	Ground to negative supply voltage	25	V
	Ground to positive supply voltage	18	V
	Differential input voltage	±5	V
V_{IN}	Input voltage[1]	±15	V
	Maximum power dissipation, T_A=25°C (still-air)[2] N package D package	 1420 1040	 mW mW
	Output short-circuit duration	10	s
T_A	Operating temperature range LM219 LM319	-25 to +85 0 to +70	°C
T_{STG}	Storage temperature range	-65 to +150	°C
T_{SOLD}	Lead soldering temperature (10sec max)	300	°C

NOTES:
1. For supply voltages less than ±15V, the absolute maximum rating is equal to the supply voltage.
2. Derate above 25°C, at the following rates:
   N package at 11.4mW/°C
   D package at 8.3mW/°C

DC ELECTRICAL CHARACTERISTICS

V_S=±15V, -25°C ≤ T_A ≤ 85°C for LM219, 0°C ≤ T_A ≤ 70°C for LM319, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	LM219			LM319			UNIT
			Min	Typ	Max	Min	Typ	Max	
V_{OS}	Input offset voltage[1, 2]	R_S≤5kΩ, T_A=25°C Over temp.		0.7	4.0 7		2.0	8.0 10	mV
I_{OS}	Input offset current[1, 2]	T_A=25°C Over temp.		30	75 100		80	200 300	nA
I_B	Input bias current[1]	T_A=25°C Over temp.		150	500 1000		250	1000 1200	nA nA
A_V	Voltage gain	T_A=25°C	8	40		8	40		V/mV
V_{OL}	Saturation voltage	V_{IN}≤-10mV, I_{OUT}=25mA, T_A=25°C, V+≥4.5V, V-=0 V_{IN}≤-10mV, I_{OUT}=3.2mA		0.75 0.3	1.5 0.6		0.75 0.3	1.5 0.4	V
I_{OH}	Output leakage current	V-=0V, V_{IN}≥10mV V_{OUT}=35V, T_A=25°C		0.2	10		0.2	10	µA
V_{IN}	Input voltage range	V_S=±15V V+=5V, V-=0V	 1	±13	 3	 1	±13	 3	V
V_{ID}	Differential input voltage				±5			±5	V
I^+	Positive supply current	V+=5V, V-=0V, T_A=25°C		4.3			4.3		mA
I^+	Positive supply current	V_S=±15V, T_A=25°C		8.0	12.5		8.0	12.5	mA
I^-	Negative supply current	V_S=±15V, T_A=25°C		3.0	5.0		3.0	5.0	mA

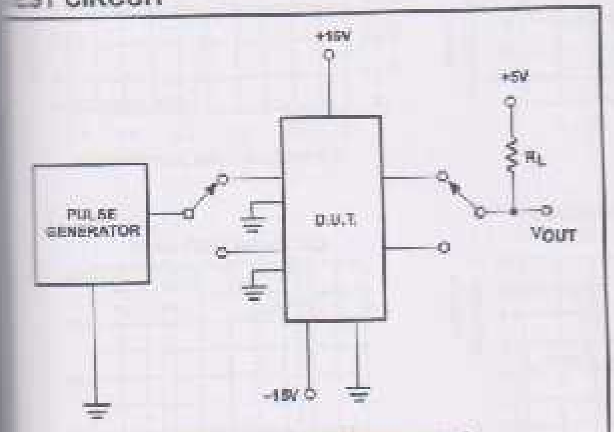
NOTES:
1. V_{OS}, I_{OS} and I_B specifications apply for a supply voltage range of V_S=±15V down to a single 5V supply.
2. The offset voltages and offset currents given are the maximum values required to drive the output to within 1V of either supply with a 1mA load. Thus these parameters define an error band and take into account the worst case effects of voltage gain and input impedance.

AC ELECTRICAL CHARACTERISTICS

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			Min	Typ	Max	
[illegible]	Response time[1]	$V_S=\pm15V$, $T_A=25°C$ $R_L=500\Omega$ (see test figure)		80		ns

NOTES:
1. The response time specified is for a 100mV step with 5mV overdrive.

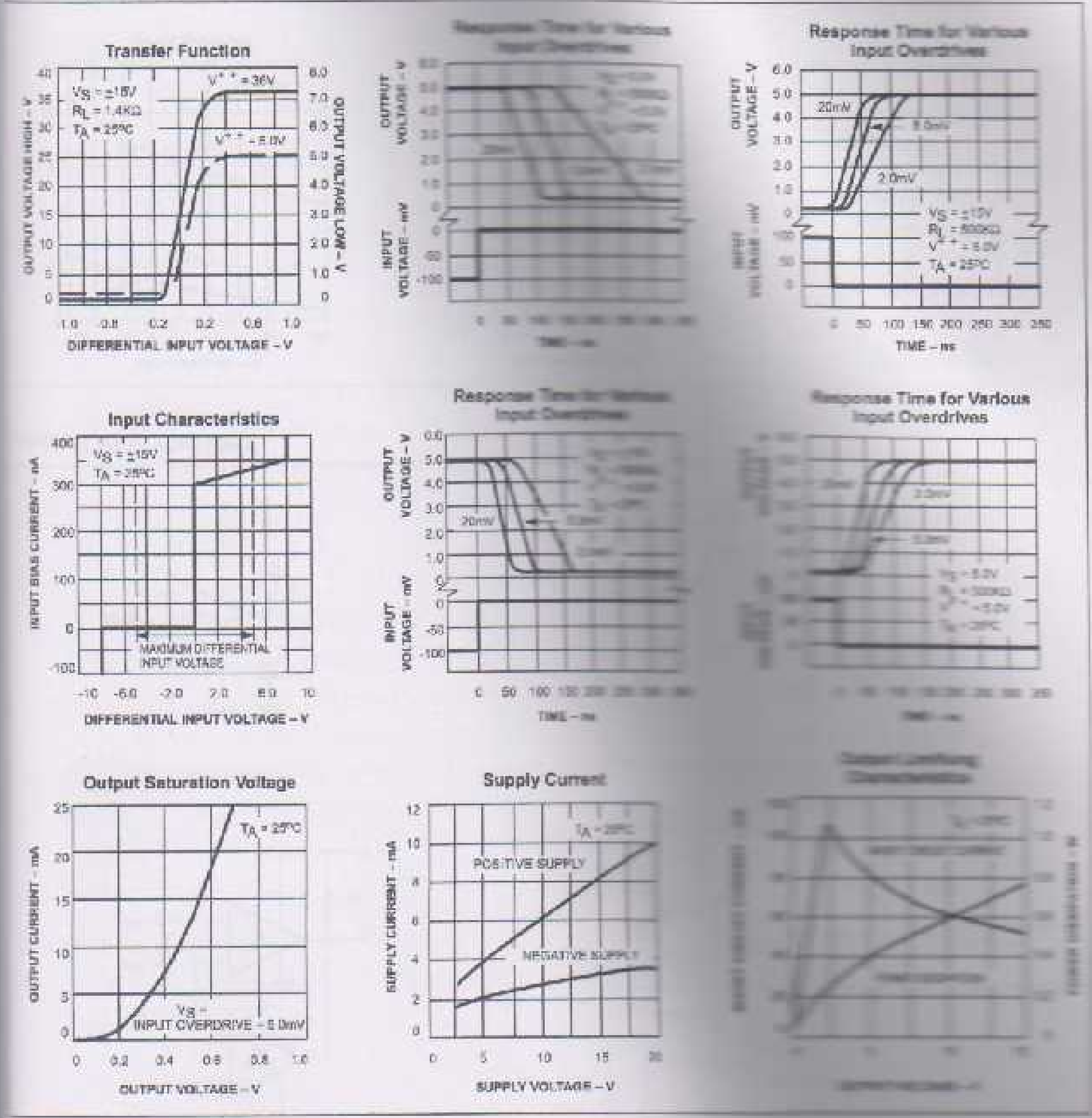
TEST CIRCUIT



Response Time Measurement

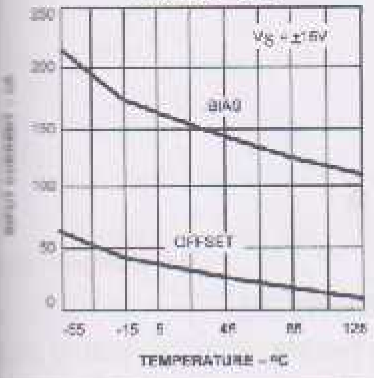
Dual voltage comparator LM219/319

TYPICAL PERFORMANCE CHARACTERISTICS

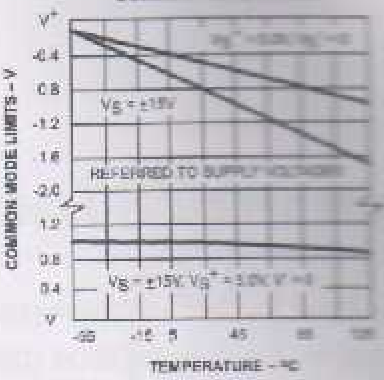


TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

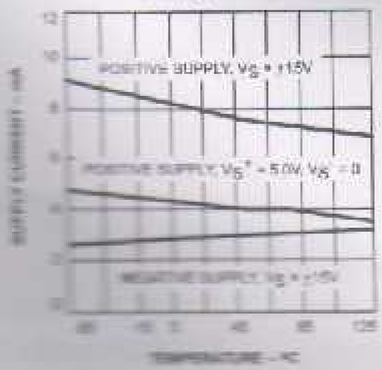
Input Currents



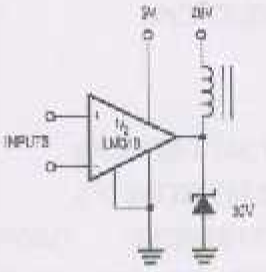
Common-Mode Limits



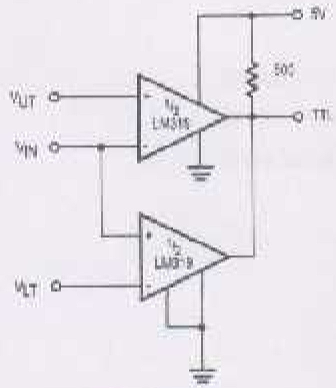
Supply Current



TYPICAL APPLICATIONS

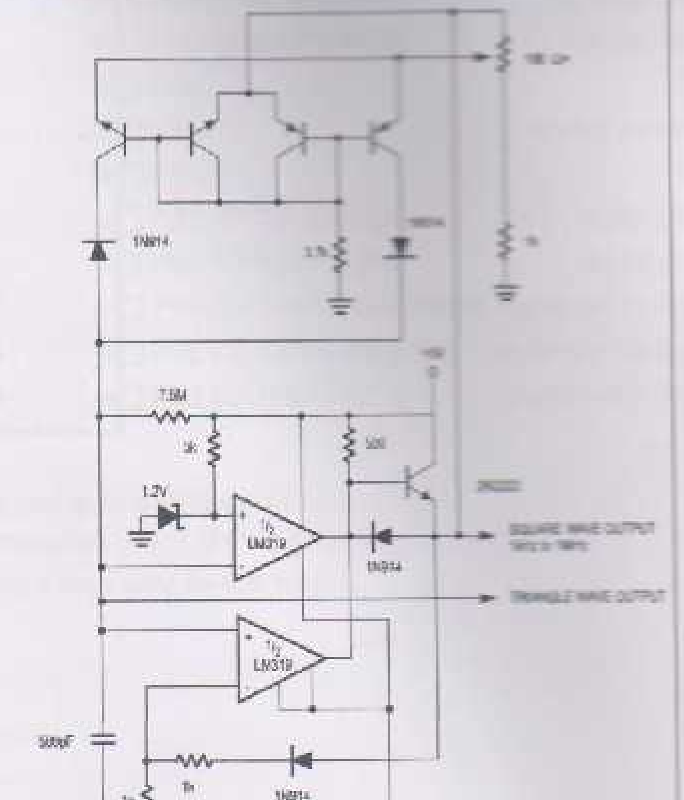


Relay Driver



Window Detector

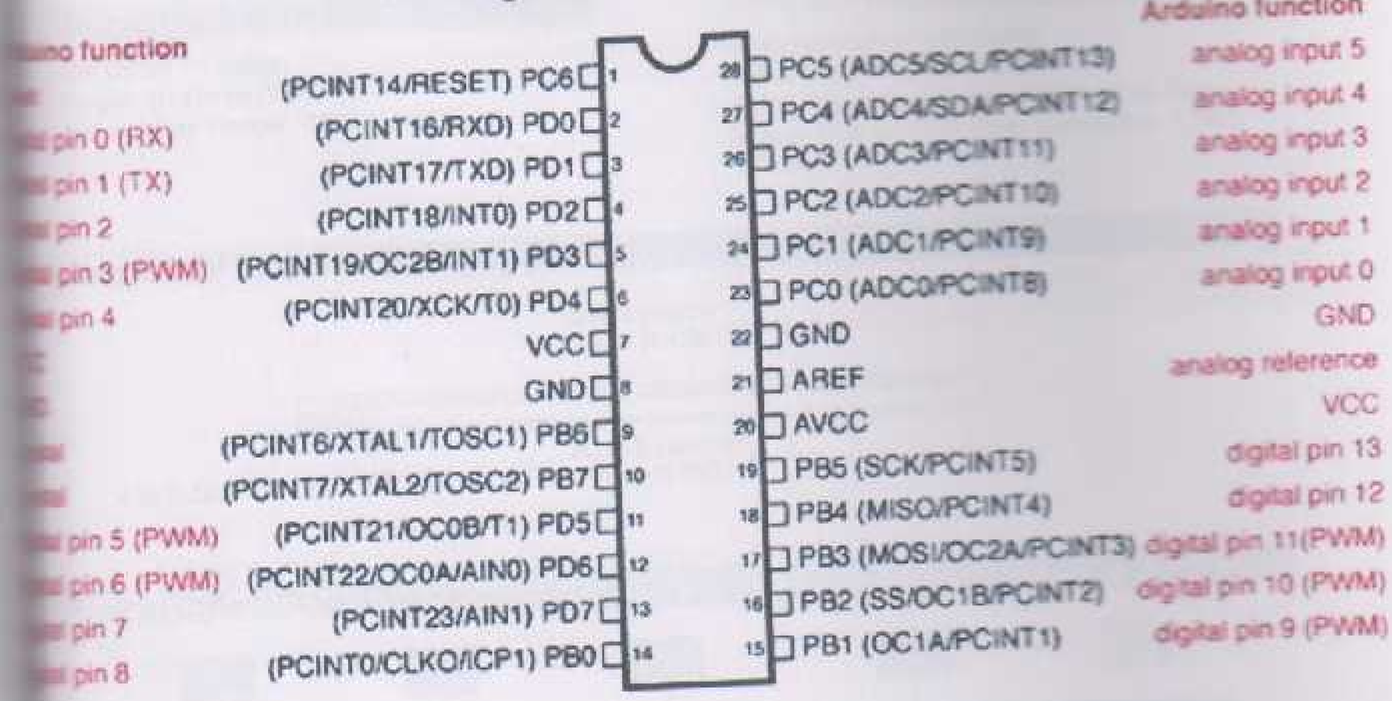
NOTES:
V_{OUT} = 5V for $V_{LT} < V_{IN} < V_{UT}$
V_{OUT} = 0V for $V_{IN} < V_{LT}$ or $V_{IN} > V_{UT}$



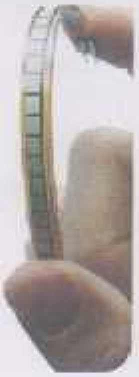
NOTE:
Frequency adjust must be buffered for $R_L \leq 10\Omega$

Wide Range Variable Oscillator

ATmega168/328 Pin Mapping



Digital Pins 11,12 & 13 are used by the ICSP header for MISO, MOSI, SCK connections (Atmega168 pins 17,18 & 19). Avoid low-impedance loads on these pins when using the ICSP header.



FLEX SENSOR FS

Features

- Angle Displacement Measurement
- Bends and Flexes physically with motion device
- Possible Uses
  - Robotics
  - Gaming (Virtual Motion)
  - Medical Devices
  - Computer Peripherals
  - Musical Instruments
  - Physical Therapy
- Simple Construction
- Low Profile

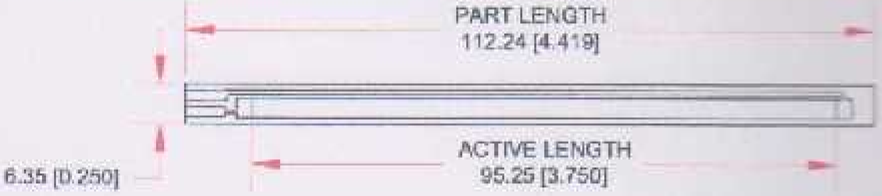
Mechanical Specifications

-Life Cycle: >1 million
-Height: ≤0.43mm (0.017")
-Temperature Range: -35°C to +80°C

Electrical Specifications

-Flat Resistance: 10K Ohms
-Resistance Tolerance: ±30%
-Bend Resistance Range: 60K to 110K Ohms
-Power Rating : 0.50 Watts continuous. 1 Watt Peak

Dimensional Diagram - Stock Flex Sensor

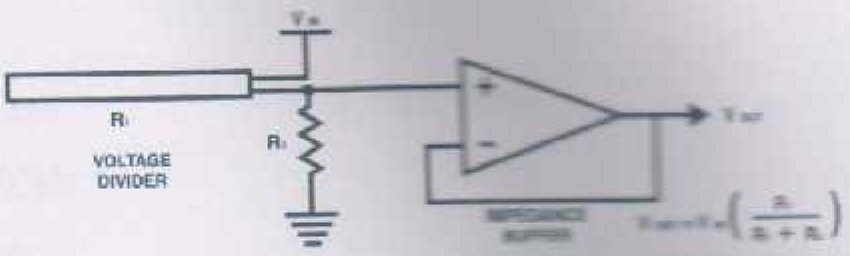


How to Order - Stock Flex Sensor

FS	—	L	—	0095	—	103	—	ST
Series		Model		Active Length		Resistance		Connectors
FS = Flex Sensor		L = Linear		0095 = 95.25mm		103 = 10 KOhms		ST = Solder Tab

How It Works

BASIC FLEX SENSOR CIRCUIT:



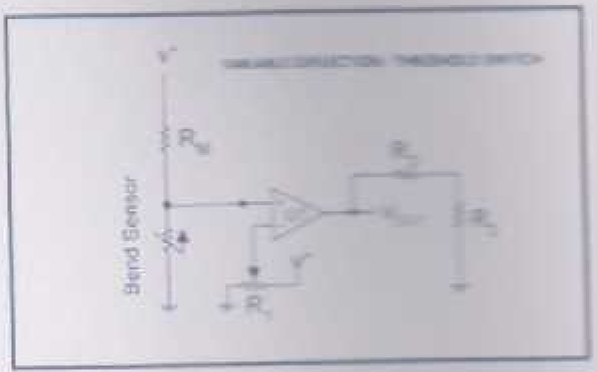
Following are notes from the ITP Flex Sensor Workshop

"The impedance buffer in the [Basic Flex Sensor Circuit] (above) is a single sided operational amplifier, used with these sensors because the low bias current of the op amp reduces error due to source impedance of the flex sensor as voltage divider. Suggested op amps are the LM358 or LM324."

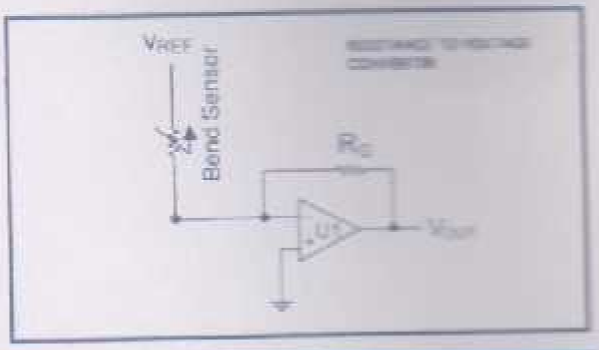
"You can also test your flex sensor using the simplest circuit, and skip the op amp."

"**Adjustable Buffer** - a potentiometer can be added to the circuit to adjust the sensitivity range."

"**Variable Deflection Threshold Switch** - an op amp is used and outputs either high or low depending on the voltage of the inverting input. In this way you can use the flex sensor as a switch without going through a microcontroller."



"**Resistance to Voltage Converter** - use the sensor as the input of a resistance to voltage converter using a dual sided supply op-amp. A negative reference voltage will give a positive output. Should be used in situations when you want output at a low degree of bending."



Window power DC Motor LH

Quick Details

Place of Origin:	Taiwan	Brand Name:	Rebeck	Model Number:	HY-2740A
Type:	DC Motor	Use:	Window	Motor:	Brushless
Voltage:	12V	Car Window:	Automobile parts		

Packaging & Delivery

Packaging Detail: 20pcs/ctn.

Delivery Detail: 30-45 days

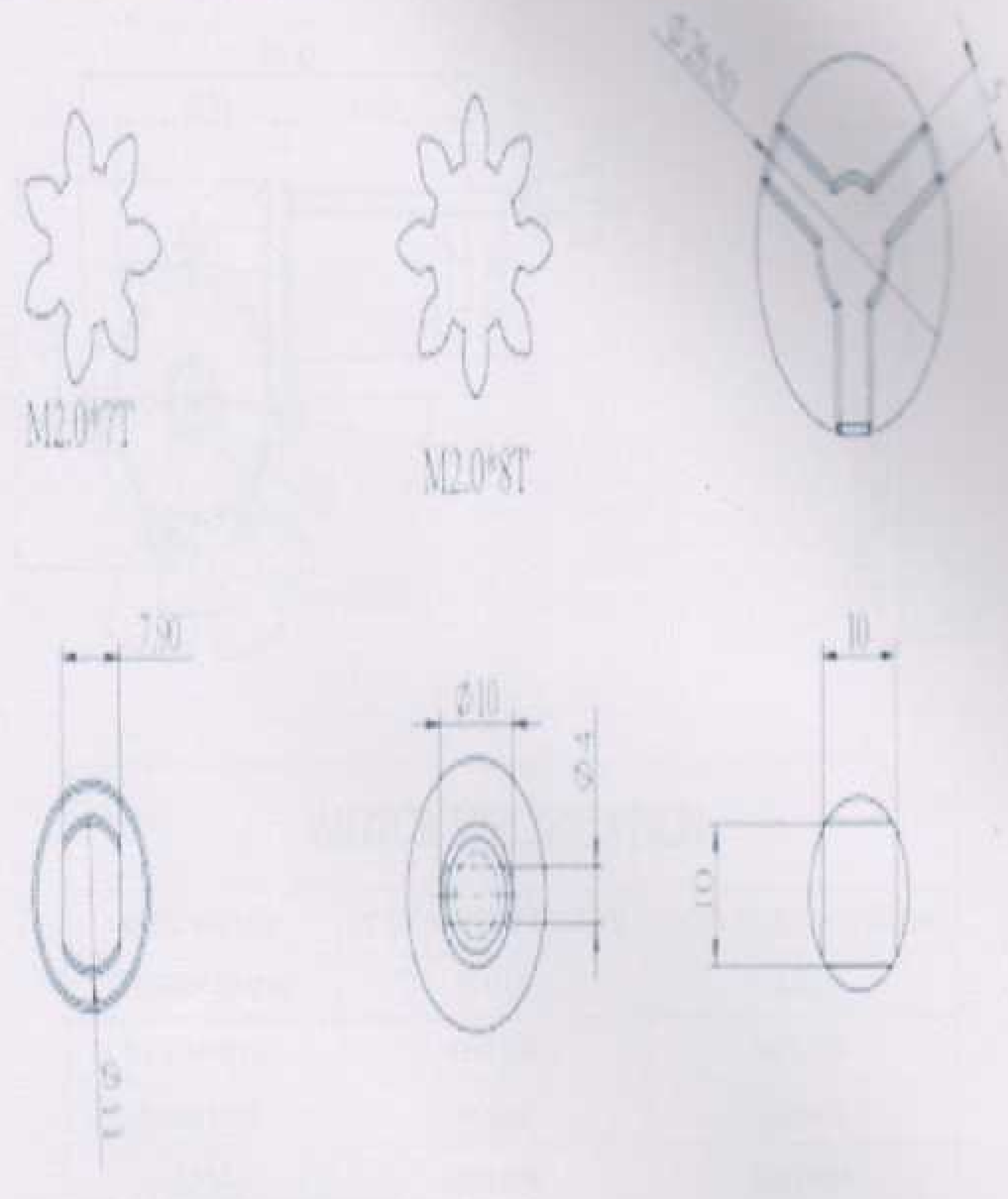
Specifications

Key Features:
For ASIA type power window motor.
Noise<52db

1.Stall: 10 +/-2.5Nm, 30A (max) for 12V, 15A (max) for 24V.
2.For automation products...etc.
3.DC12V,24V(option).
4.Rated Speed: 90 +/-10 rpm
5.insulation resistance: 1M ohm min.
6.Low Noise<52dbA
7.OEM,ODM

Window power DC Motor LH

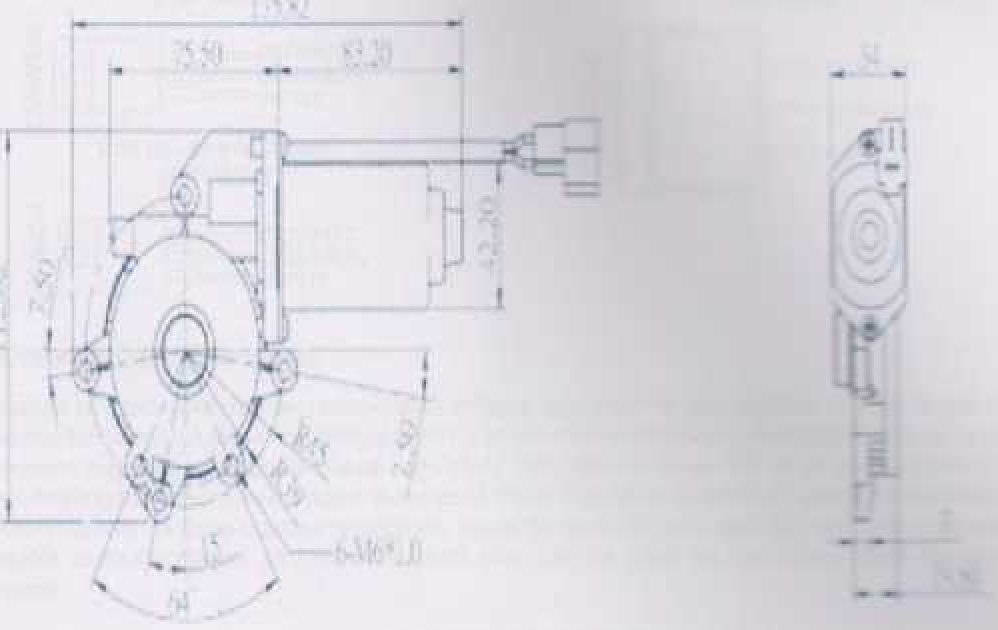
AVAILABLE PINION:



*CUSTOMIZE PINION IS WELCOME.

Window power DC Motor LH

HY-2740A SERIES GEAR MOTOR



MOTOR SPECIFICATION

RATED VOLTAGE	DC 12V AT MOTOR TERMINAL	DC 24V AT MOTOR TERMINAL
NO LOAD CURRENT	3A MAX	2A MAX
NO LOAD SPEED	90±10 RPM	90±10 RPM
RATED LOAD	9A MAX	4.5A MAX
3 N*m	62±10 RPM	62±10 RPM
STALL	10±2.5 N*m	10±2.5 N*m
	30A MAX	15A MAX
INSULATION RESISTANCE	1M Ohm min	1M Ohm min
DIELECTRIC STRENGTH	AC 600V BETWEEN CASING AND TERMINAL FOR 1 SEC	