NEAR EAST UNIVERSITY

Faculty of Engineering

Department of Electrical and Electronic Engineering

APPLICATIONS OF ELECTRICAL & ELECTRONICS SCIENCE IN BIOMEDICS

Graduation Project
EE – 400

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ABSTRACT

Dawn of every day brings with us such innovations that give heed to our dwindling sprits and altogether change their orientation .The stimulus to carve thoughts and human skill in such a way that could pave the way to progress ,and bid farewell to the realm of darkness of ignorance provoked me to highlight the entity of medicine with the help of electronics.

The lineaments of my project include some of mostly used medical devices like ECG, pacemakers, robotics ,CT scan, Angiography and also the new technologies like ergometer, mobile micro robotics in telemedicine and use of X rays in nanopatterned surface are enough to make applications of electronics vivid.

Electrical and electronic applications of biomedics are not only helping in early diagnosis & examinations but also therapeutically & in patient monitoring. So this way they have a substantial impact in improving quality of human health care.

I am adamant that the effort I have made to highlight the medical devices & the integrated technologies will certainly help you to have an idea that how how biomedical applications are eradicating human beings from the old lethargic services.

I'm confident that my effort will open up the threshold of a new notion.

CONTENTS

INTRODUCTION

This project is mainly concerned with the Electrical & Electronic applications of Biomedics that are being widely used throughout the world. It starts with the theory of medical instrumentation, design and biopotential theories.

Some of the applications of biomedics with which we all are quite familiar like angiography, computed Tomography, Magnetic resonance imaging, pacemaker technology, Electrocardiogram etc but we hardly know how do they work. The proceeding chapters contain the information of how and why do these medical devices are actually used.

The thesis contains latest studies about use of X-rays in nanopatterened surfaces and also about ergometer that has played an important role in reducing health care costs especially in developing countries.

Mobile micro robotics that is a rapidly developing technology is very good example of biomedical application .A part of this thesis is about Conventional Electromagnetic motors, Piezelectronic linear actuators, Flextentional amplifiers and finally a brief account on role of robotics in surgery.

The last chapter gives an idea about hazards of electricity to humans and the safety precautions suggested for protection by implementation of Electrical Engineering.

I hope that the gist of my project will give, at least the remote idea to readers.

1. MEDICAL INSTRUMENTATION

1.1 What Is A Medical Instrument?

There are many different types of medical instruments. The ones on which we concentrate in this thesis are those that monitor and analyze physiological signals from a patient. Figure 1.1 shows a block diagram that characterizes such instruments. Sensors measure the patient's physiological signals and produce electrical signals (generally time-varying voltages) that are analogs of the actual signals.

A set of electrodes may be used to sense a potential difference on the body surface such as an ECG or BEG. Sensors of differ6nt types are available to transduce into voltages such variables as body core temperature and arterial blood pressure. The electrical signals produced by the sensors interface to a processor, which is responsible for processing and analysis of the signals. The processor block typically includes a microprocessor for performing the necessary tasks. Many instruments have the ability to display, record, or distribute through a network either the raw signal captured by the processor or the results of its analysis. In some instruments, the processor performs a control function. Based on the results of signal analysis, the processor might instruct a controller to do direct therapeutic intervention on a patient [closed loop control] or it may signal a person that there is a problem that requires possible human intervention [open loop control].

Let us consider two types of medical instrumentation and see how they fit this block diagram. The first is an intensive care unit (ICU) system, a large set of instrumentation that monitors a number of patient's simultaneously. The second is a cardiac pacemaker so small that it must fit inside the patient.

In the case of the ICU, there are normally several sensors connected to each patient receiving intensive care, and the processor (actually usually more than one processor) monitors and analyzes all of them. If the processor discovers an abnormality, it alerts the medical staff, usually with audible alarms. A display permits the staff to see raw data such as the ECG signals for each patient and also data obtained from the analysis such as numerical readouts of heart rate and blood pressure. The network connects the bedside portion of the instrumentation to a central control in the ICU.

Another network might connect the ICU system to other databases remotely located in the hospital. An example of a closed loop device that is sometimes used is an infusion pump. Sensors monitor fluid loss as the amount of urine collected from the patient, and then the processor instructs the pump to infuse the proper amount of fluid into the patient to maintain fluid balance, thereby acting as a therapeutic device.

Now consider Figure 1.1 for the case of the implanted cardiac pacemaker. The sensors are electrodes mounted on a catheter that is placed inside the heart. The processor is usually a specialized integrated circuit designed specifically for this ultra-low-power application rather than a general-purpose microprocessor. The processor monitors the electrogram from the heart and analyzes it to determine if the heart is beating by itself if it sees that the heart goes too long without its own stimulus signal, it fires an electrical stimulator (the controller in this case) to inject a large enough current through the same electrodes as those used for monitoring. This stimulus causes the heart to beat. Thus this device operates as a closed loop therapy delivery system. The early pacemakers operated in an open loop fashion, simply driving the heart at some fixed rate regardless of whether or not it was able to beat in a normal physiological pattern most of the time. These devices were far less satisfactory than their modem intelligent cousins. Normally a microprocessor-based device outside the body placed over a pacemaker can communicate with it through telemetry and then display and record its operating parameters. Such a device can also set new operating parameters such as amplitude of current stimulus. There are even versions of such devices that can communicate with a central clinic over the telephone network. Thus, we see that the block diagram of a medical instrumentation system serves to characterize many medical care devices or systems.

1.2 Evolution of Microprocessor-Based Systems

In the last decade, the microcomputer has made a significant impact on the design of biomedical instrumentation. The natural evolution of the microcomputer-based instrument is toward more intelligent devices. More and more computing power and memory are being squeezed into smaller and smaller spaces. The commercialization of laptop PCs with significant computing power has accelerated the technology of the battery-powered, patient-worn portable instrument. Such an instrument can be truly a personal computer looking for problems specific to a given patient during the patient's daily routines. The ubiquitous PC itself evolved from minicomputers that were developed for the biomedical instrumentation laboratory, and the PC has become a powerful tool in biomedical computing applications. As we look to the future, we see the possibility of developing instruments to address problems that could not be previously approached because of considerations of size, cost, or power consumption.

The evolution of the microcomputer-based medical instrument has followed the evolution of the microprocessor itself (Tompkins and Webster, 1981). The microprocessor is now more than 20 years old. It has evolved from modest beginnings as an integrated circuit with 2,000 transistors (Intel 4004) in 1971 to the powerful central processing units of today having more than 1, 000, 000 transistors (e.g., Intel i486 and Motorola 68040).

1.3 Iterative Definition Of Medicine

Data collection is the starting point in health care. The clinician asks the patient questions about medical history, records the ECG, and does blood tests and other tests in order to define the patient's problem. Of course medical instruments help in some aspects of this data collection process and even do some preprocessing of the data. Ultimately, the clinician analyzes the data collected and decides what is the basis of the patient's problem. This decision or diagnosis leads the clinician to prescribe a therapy. Once the therapy is administered to the patient, the process continues around the closed loop with more data collection and analysis until the patient's problem is gone.

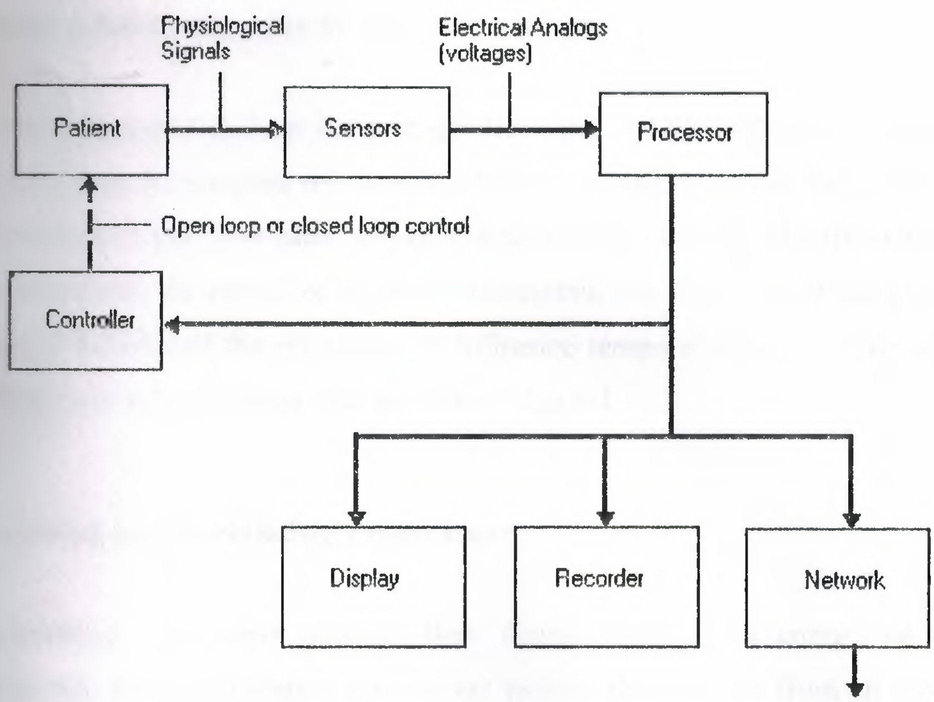


Figure 1.1 Basic elements of medical instrumentation system

The function of the medical instrument of Figure 1.1 thus appears to be a model of the medical care system itself

1.4 Alternative operational modes

Direct-Indirect Modes

Often the desire & measurand can be interfaced directly to a transducer because measurand is readily accessible or acceptable invasive procedures we available. A the desired measurand is not accessible, then we can use either another measurand that bears a known relation to the desired one or some form of energy or material that interacts with the desired measurand to generate a new measurand that is accessible examples are cardiac output (volume of blood pumped per minute by the heart), determined from measurements of respiration and blood gas, or dye dilution; morphology of internal organs, determined from x-ray shadows; and pulmonary volumes, determined from variations in thoracic electrical impedance.

Sampling and Continuous Modes

Some measurand such as body temperature and ion concentrations-change so slowly that they may be sampled infrequently. Other quantities such as the electrocardiogram and respiratory gas flow-often require continuous monitoring. The frequency content of the measurand, the objective of the measurement, the condition of the patient, and the potential liability of the physician all influence temporal aspects of the acquisition of medical data. Many unused data are often collected.

Generating and Modulating Transducers

Generating transducers produce their signal output from energy taken from the measurand, while modulating transducers receive their energy from an external source and provide their output by varying this external energy according to the measurand. For example, a photovoltaic cell is a generating transducer because it provides an output voltage related to its illumination, without any additional external energy source. However, a photoconductive cell is a modulating transducer, since to measure its change in resistance with illumination; one must apply external energy to the transducer.

Analog and Digital Modes

Signals that carry measurement information are either analog meaning continuous and able to take on any value, or digital, meaning discrete and able to take on only a finite number different values. Most currently available transducers operate in the analog mode, although some inherently digital measuring devices have recently been developed. Increased use of digital signal processing has required concurrent use of analog-to-digital and digital-to-analog converters to interface computers with analog transducers and analog display devices. Researchers have developed indirect digital transducers that use analog primary sensing elements and digital variable-conversion elements (optical shaft encoders). Also quasi-digital transducers, such as quartz-crystal thermometers, give outputs with variable frequency, pulse rate, or pulse duration that are easily converted to digital signals.

Advantages of the digital mode of operation are greater accuracy, repeatability, reliability, and immunity to noise. Also periodic calibration is usually not required. Digital numerical displays are replacing many analog meter movements because of their greater accuracy and readability. Many clinicians, however, prefer analog displays when they are determining whether a physiological variable is within certain limits or when they we looking at a parameter that can quickly change, such as beat-to-beat heart rate. In the latter case, digital displays often change numbers so quickly that they are very difficult and annoying to observe.

Real-Time and Delayed-Time Modes

Of course transducers must acquire signals in real time as the signals actually occur. The output of the measurement system may not display the result immediately, however, since some types of signal processing, such as averaging and transformations, need considerable input before any results can be produced. Often such short delays are acceptable unless urgent feedback and control tasks depend on the output.

Deflection and Null Modes

For instruments that operate in the deflection mode, the output signal produces an effect that is opposed by a spring or similar device so that a displacement proportional to the quantity measured can be displayed. For example, the torque produced by current flowing through a D'Arsonval meter movement is opposed by a spring so that displacement of the needle is proportional to input current.

Instruments operating in the null mode utilize a detector of imbalance between the unknown quantity and a known calibrated opposing quantity. The output is read as the value of the opposing quantity for a balanced detector at maximum sensitivity. The Null-type device is generally more accurate because the unknown is compared directly with a standard and the detector of imbalance can have high sensitivity because only a small range near zero need be covered. The null detector does not have to be calibrated, since it is used only to detect the presence or absence of a signal. The major disadvantage of null methods is the typically poor dynamic response, even when automatic balancing devices are used.

1.5 Medical Measurement Constraints

The medical instrumentation is designed to measure various medical and physiological parameters. The principal measurement and frequency ranges for each parameter are major factors that affect the design of all the instrument components. Most of the parameter measurement ranges are quite low compared with nonmedical parameters in most industries. Note for example that most voltages are in the microvolt range and that pressures are low (about 100 mm Hg = 1.93 psi = 13.3 kPa). Also note that all the signals are in the audio frequency range or below and that many signals consist of dc and very low frequencies. These general properties of medical parameters limit the practical choices available to designers for all aspects of instrument design.

Many crucial variables in living systems are inaccessible because the proper measurand transducer interface cannot be achieved. Unlike many complex physical systems, a biological system is of such a nature that it is not possible to turn it off and remove parts of it during the measurement procedure. Even if interference from other physiological systems can be avoided, the physical size of many transducers prohibits the formation of a proper interface. Either such inaccessible variables must be measured indirectly as just described, or corrections must be applied to data that are affected by the measurement process. The cardiac output is an important measurement that is obviously quite inaccessible.

Variables measured from the human body or from animals are seldom deterministic. Most measured quantities vary with time, even when all controllable factors are fixed. Many medical measurements vary widely among normal patients, even when conditions are similar. This inherent variability has been documented at the molecular and organ levels, and even for the whole body. There are many internal anatomical variations that accompany the obvious external differences between patients. Large tolerances on physiological measurements are partly the result of interactions between many physiological systems. Many feedback loops exist between physiological systems and many of the interrelations are poorly understood. It is seldom feasible to control or neutralize the effects of these other systems on the measured variable. The most common method of coping with this variability is to assume empirical statistical and probabilistic distribution functions. Single measurements are then compared with these norms.

Newly all biomedical measurements depend either on some form of energy being applied to the living tissue or on some energy being applied as an incidental consequence of transducer operation. X-ray and ultrasonic imaging techniques and electromagnetic or Doppler ultrasonic blood flow meters all depend on externally applied energy interacting with living tissue. Safe levels of these various types of energy are difficult to establish because many mechanisms of interaction are not well understood. The heating of tissue is one effect that must be joined, because even reversible physiological damages can affect measurements. Damage to tissue at the molecular level has been demonstrated in some instances at surprisingly low energy levels.

Operation of instruments in the medical environment imposes important additional constraints. Equipment must be reliable, simple to operate, and capable of withstanding physical abuse and exposure to corrosive chemicals. Electronic equipment must be designed to minimize electricshock hazards .The safety of patients and medical personnel must be considered in all phases of design and testing of instruments.

1.6 Classifications Of Biomedical Instruments

The study of biomedical instruments can be approached from at least four viewpoints. Techniques of biomedical measurement can be grouped according to the quantity that is transduced, such as pressure, flow, or temperature. One advantage of this classification is that different methods for measuring any quantity can be compared readily.

A second classification scheme uses the principle of transduction, such as resistive, inductive, capacitive, ultrasonic, or electrochemical. Different applications of each principle can be used to strengthen understanding of each concept; also new applications may be more apparent.

Measurement techniques can be studied separately for each physiological system, such as the cardiovascular, pulmonary, nervous, or endocrine systems. This approach isolates all the important measurements for specialists who need to know only about a specific area, but it results in considerable overlap of principles of transduction.

Finally, biomedical instruments can be classified according to the clinical medicine specialties, such as pediatrics, obstetrics, cardiology, or radiology. This approach is valuable for medical personnel who are interested in specialized instruments.

2. Electrical Potential In Human Heart

2.1 Anatomical Structure of heart

The heart is a muscle, about the size of your fist that is encased in a sac called the pericardium. The pericardium helps to keep the heart in position and protects it from getting hurt. The pericardium and the heart are separated by a layer of lubricating fluid, which allows the heart to pump freely inside the walls of the chest. The heart is made up of three layers of muscle, the endocardium, myocardium and epicardium. The myocardium makes up about seventy five percent of the heart tissue. The epicardium is a thin lining that covers the myocardium. There is a layer called the endocardium that is between the myocardium and the inside of the heart. The endocardium acts as the inner covering of the heart and protects the myocardium. The heart functions as a pump that circulates nourishment and oxygen to, and carbon dioxide and waste away from, tissues and organs of the body. The heart is separated into four different chambers through which blood is pumped. A thick wall of muscle called the septum, which divides the heart into two halves, separates the heart. Each half is then separated into an upper and lower chamber by valves. The upper chambers are called the atria and are the inputs to the heart. The lower chambers are called the ventricles and are the outputs of the heart. The valves that separate the upper and lower chambers are called the atrioventriclular valves. The valve that separates the right atrium from the right ventricle is called the tricuspid valve and the valve that separates the left atrium from the left ventricle is called the mitral valve. A different set of valves controls the flow of blood from each ventricle to the main arteries. The valve that separates the right ventricle from the pulmonary artery, the artery that carries blood to the lungs, is called the pulmonary valve. The aortic valve is the valve that separates the Left ventricle from the aorta, the main artery that carries blood to the rest of the body's organs and tissues.

2.2 Generation of electrical potential in a Cardiac Cell

The heart is a pumping organ of the body that contracts and relaxes and pumps blood throughout the body. The contraction and relaxation is due to movement of ions through the semipermiable membrane of cardiac cells. The movement of ions across the membrane changes the concentration of ions within and outside the cells, which results in an action potential and due to this action potential depolarization and depolarization of cells occur. The ions that are responsible for generation of an action potential in a cardiac cell are mainly sodium and potassium that move through sodium-potassium pump. The outward movement of sodium in exchange with potassium creates the difference of ionic concentration which in-turn results in an electrical potential. At rest concentration of positive sodium ions outside the cell is higher then the concentration of sodium inside the cell. This electrical potential is negative with respect to the outside resulting in a resting potential of a negative seventy to ninety mill volts. When the cell is stimulated the sodium ions rush into the cell forcing potassium out which results in the action potential. This action potential results in the inside of the cell being twenty to forty mill volts more positive than the outside and the cell is said to have depolarized. The cell is repolarized when the sodium-potassium pump pumps the sodium back out of the cell and the potassium back into the cell, which resets the cell so, it can depolarize again. An ionic electrical conduction is started by the depolarization of one cell, which in turn triggers the next cell causing an action potential. This situation causes a triggering of cells in a cascade effect making all the cells depolarize.

Conduction of Electrical Stimulus

The electro conduction system of the heart is a complicated system of the body that begins in the right atrium at the sinoatrial (SA) node. The SA node, a small bundle of cells located on the back wall of the right atrium, serves as a pacemaker for the heart. The SA node fires, by self-excitation, an electrical impulse that is spread across the right atrium and to the left atrium by the Bachman's bundle so that both atria can contract at the same time. The contraction of the atria forces blood from the atria to the ventricles through their respective valves. The impulse that is started at the SA node then travels to the atrioventricular (AV) node. The AV node acts as a delay line to slow down the action potential along the internal electro conduction system. This is done so that all of the blood from the atria can be emptied into the ventricles before the ventricles contract. The action potential then travels from the AV node to the Purkinje fibers. The Purkinje fibers are arranged in two bundles, one bundle branching to the muscle in the right ventricle and the other branching to the muscles in the left ventricles. The action potential moves through these fibers very rapidly and spreads throughout the ventricles at two to four meters per second. This causes the ventricles to pump fast and hard. This forces the blood though their respective valves out to the body at an extremely fast rate. The contraction of the ventricles is known as systole. The relaxation of the ventricles is known as diastole. The electro conduction of the heart starting at the SA node and traveling through the AV node to the Purkinje fibers creates mass electrical signal that can be detected by placing electrodes on a patient's chest or extremities. This electrical signal can be mechanically plotted and the resultant plot is called an electrocardiogram (ECG). The letters on the ECG represent different functions that occur in the bean. The P-wave indicates atrial contraction. Ventricular contractionis represented by the QRS complex, and the T-wave indicates ventricular repolarization.

2.3 Pathological conditions of the Heart

The heart is a system that has to be exact in all of its functions from start to finish for each beat to beat successfully. If a problem occurs, severe or minor, it can cause death for the patient. Physicians can look at a simple ECG reading and can tell if the patient is having any problems that can either be fatal or could lead to something fatal. Some heart problems that plague humans around the world are arrhythmias.

Arrhythmias are abnormal beats that can be detected on the ECG. Two of the arrhythmias that people with heart problems encounter are tachycardia and bradycardia. Tachycardia is a problem in which the heart beats at a rate faster than the normal human heart rate. Treatment for tachycardia consists of cardio version or the delivery of a broad depolarizing shock to a restricted region of the heart. Rapid bursts of pacemaker impulses timed and placed at the proper time can often stop the tachycardia. Bradycardia is a problem in which the heart beats at a rate slower than the normal human heart rate. An implanted pacemaker can restore the lower heart rate to a more physiological value that will improve cardiovascular function. Fibrillation is another major problem that affects the heart. Fibrillation is the uncontrolled beating of different parts of the heart. Ventricular fibrillation is a fatal arrhythmia of the heart in which the victim will die in minutes if it is not corrected. Atrial fibrillation is a less serious arrhythmia because the ventricles are still pumping. However it can lead to problems if it is not corrected. Heart block is another problem caused by the interruption of the internal electroconduction system of the heart. These are a few heart problems that people encounter that can be conquered with help from pacemakers, defibrillators, and modern technology.

2.4 Pacemaker

Pacemaker technology has expanded immensely over the last three decades. Each phase of development has been associated with clinical improvements each step of progress has led to smaller, more reliable devices with greater programmability. The longevity of devices has been advanced with better generator technology and better design. The first devices used asynchronous pacing which had a significant effect in reducing the mortality of surgically induced complete heart block. Ventricular demand pacemakers overcame the problem of asynchronous competitive pacing, but at the same time patients exposed to pacemaker syndrome. Atrioventricular sequential pacing restored atrioventricular synchrony, resulting in hemodynamic improvement, but like the other improvements it caused the phenomenon of pacemaker-mediated tachycardia.

Alternative dual chamber modes and algorithms have brought solutions to these and other problems. Adaptive-rate devices have been of benefit to patients with chronotropic incompetence and are now incorporating increasing variety of biosensors. Such devices offer improved survival and quality of life, but at the cost of increased complexity. Amazingly, the expense of the pacemaker has not increased much over the years. Cost still remains the major limitation to the use of such readily available and advantageous technology. Nearly all of the problems that pacing has presented over the years have been overcome, but the increasing complexity of pacemaker technology is now a major limitation to its proper use.

In future generations, developments in the field of microprocessor technology will lead to greater flexibility in the self-adjustment of rate, output, and the overall sensitivity of pacemakers. The continued innovation of programmability and telemetry will increase the diagnostic capabilities of pacemakers. Systems are being developed which can facilitate storing of patient details and which can diagnose rhythm disturbances using sophisticated algorithms. Sensors will be combined with electrogram analysis to differentiate between physiological and pathological alterations in hemodynamics in such a way that appropriate adjustments can be initiated. Pacemaker technology that is self-adjusting will evolve that can differentiate arrhythmias and initiate the appropriate pacing modality. Progress in battery technology will reduce generator size further without effects on longevity. Generator microprocessors will permit more flexible programming of algorithms that will satisfy the patient's changing requirements. Future applications of implantable pacemakers need to be able to interact in a patient's body with internal defibrillators. Large amounts of energy that passes though the pacing electrode may cause damage at the electrode - myocardium interface. This damage can temporarily or permanently alter the pacing and sensing thresholds of the pacemaker. A pacemaker may be reprogrammed or experience a change in the sensing or pacing thresholds after a shock from a defibrillator. In future generations, it is important that the pacemaker be able to protect itself from excessive energy and shocks caused by a defibrillation.

Benefits of Pacemaker Technology

Pacemaker technology has expanded immensely over the last three decades. Each phase of development has been associated with clinical improvements each step of progress has led to smaller, more reliable devices with greater programmability. The longevity of devices has been advanced with better generator technology and battery design. The first devices used asynchronous pacing which had a significant effect in reducing the mortality of surgically induced complete heart block. Ventricular demand pacemakers overcame the problem of asynchronous competitive pacing, but at the same time patients exposed to pacemaker syndrome. Atrioventricular sequential pacing restored atrioventricular synchrony, resulting in hemodynamic improvement, but like the other improvements it caused the phenomenon of pacemaker-mediated tachycardia. Alternative dual chamber modes and algorithms have brought solutions to these and other problems. Adaptive-rate devices have been of benefit to patients with chronotropic incompetence and are now incorporating increasing variety of biosensors. Such devices offer improved survival and quality of life, but at the cost of increased complexity. Amazingly, the expense of the pacemaker has not increased much over the years. Cost still remains the major limitation to the use of such readily available and advantageous technology. Nearly all of the problems that pacing has presented over the years have been overcome, but the increasing complexity of pacemaker technology is now a major limitation to its proper use.

2.5 Defibrillators

Defibrillators are devices that are used to apply a strong electrical shock to the heart. The shock changes ventricular fibrillation to an organized ventricular rhythm or changes a very rapid and ineffective cardiac rhythm to a slower, more effective rhythm.
This device helps treat cardiac disorders, which include ventricular fibrillation, ventricular tachycardia, atrial fibrillation, and atrial flutter. The idea of fibrillation started round 1888 when Mac William, a clinician, noted that ventricular fibrillation might be the cause of sudden death. It was 1899 when Provost and Patella stumbled upon the concept of electrical defibrillation on animals. [101 Many scientists in the early nineteenth century studied and experimented with the idea of how to reduce tachyarrhythmias using electrical defibrillation.

Working of defibrillator

Each Internal Cardiac Defibrillator (ICD) is designed to automatically detect episodes of bradycardia, ventricular tachycardia (VT), fast ventricular tachycardia (FVT), and ventricular fibrillation (VF). When an arrhythmia is detected, the device will deliver the programmed pacing, cardioversion, or defibrillation therapy. The device has two independently programmable tachyarrhythmia detection procedures, one for VT and a second for VP. The detection of FVT can be programmed via either VT or VP detection. Generally up to four therapies can be independently programmed for each arrhythmia type (VT, FVT, and VF). The device generally has two electrodes. One bipolar electrode system serves for both defibrillation and sensing the cardiac electrical waveform. This lead system uses an intravascular catheter positioned in the superior vena cava near the right atrial junction with the cathode having the form of a flexible rectangular patch placed over the left ventricular apex.

3. APPLICATION OF BIOMEDICAL SCIENCE AND TECHNOLOGY

3.1 Fuzzy Logic in Biomedicine

Classical Logic and Fuzzy Logic

Logic can be defined as the science of formal principles of reasoning. There are different kinds of logic. The classical Aristotelian Logic (dual, binary, bivalued logic) includes three main principles; called The Laws of Thought. The first one is the law of identity, which states,``Everything is what it is``. The Law of Contradiction is the second rule which can be explained by the world ``The statements of A is B and A is not B cannot be both true``. The last one, The Law of Excluded Middle, states, ``Of two contradictory judgements one must be true and the other must be false``. But in everyday practice and in linguistic statements there are many cases that cannot be explained and solved by the principles of the classical logic, especially by The Law of Contradiction and The Law of Excluded Middle States. Fuzzy logic is a superset of conventional (Aristotelian-Boolean) logic. Fuzzy logic uses ``Soft`` linguistic (e.g. cold, cool, warm, hot) system variables and a continous range of true values in the interval [0,1](partially truth values), rather than crisp binary ([1,0],completely true or false) decisions and assignments. There are several disciplines that have been formed by applying fuzzy reasoning. These are fuzzy sets, fuzzy, fuzzy control and fuzzy decision making. Fuzzy logic has been used in many applications in diverse fields such as pattern recognition, image and signal processing, hardware design and synthesis, layout of integrated circuits, artificial intelligence, expert and decision support systems, business and social studies.

Fuzzy Logic Application Areas in Biomedics

Biological systems are very complex and therefore it is inappropriate to apply traditional quantitative analysis methods on those systems. Medicine is essentially a continuous domain and it has the characteristics of incompleteness, nonlinearity, uncertainty, vagueness, fuzziness and inconsistency. The patho-physiological mechanisms of deceases uncertainty about normal ranges for test results, simultaneous presence of more than one condition and missing information occurring in most of the cases are the reasons for the uncertainty characteristic of the medical domain. Fuzzy principles allow us to model the pathophysiological mechanism of diseases it offers an alternative decision making path. In daily practice, internal medicine, anaesthesia, radiology, electrophysiology, pharmacokinetics and neuro-medines use fuzzy logic methods.

The most likely area of application for this theory lies in medical diagnostics. Fuzzy logic will be a bridge between the discrete world of reasoning and the continuity or reality.

3 .2 Telemedicine

Telemedicine can be defined as the use of electronic information and telecommunication technologies to enable the exchange of medical information and services across distances. Telemedicine is a valueable tool the improves the effective use of resources and that allows experts to reach patients in rural areas. iT also provides cost-effectiveness since it eliminates the travel and accommodation expenditures and prevents the raplication of resources by telemedicine applications, a patient can betreated ny a physician at a distance.Similarly physicians can make consultaions although they have thousands of kilometers between eachother. Patients records, audios, videos and images can be transferred in telemedicine application. Also patient interviews consultations, surgerys across distances, educational and administrative services are now available using video conferencing equipment.

There are two kinds of technologies used within telemedicine applicaton. The first one, called store and forward, is the storing of images, records the messages and transferring to other locations. It may include transfer of radiographs, pathological samples, MRI images, sound records or email messages.

The second one is real time synchronous conferencing. By the appropriate tools at both sides real time application is possible in almost all fields of health care. These datas can be exchanged usingwide variety of technologies. Internet is the cheapest and most commonly used amoung these technologies. Wireless networks, LAN (local area network), high speed modems, satalite based systems and ISDN(Integrated Services Digital Networks) are the other available and currently used technologies. All have specific advantages and disadvantages and should be installed considering the conditions.

Today telemedicine is a state of research and development. Although there are many implementations in several different systems, it cannot be said that telemedicine technologies are extensively used in the world. On the other hand, providing health care by telemedicine is getting popular. There are applications in almost all fields of medicine such as mental health, home care, cardiology, radiology, surgery, medical education, patient education, neurology and dermatology.

3.3 Angiography

Why is Angiograpy Done?

X-ray angiography is performed to specifically image and diagnose diseases of the blood vessels of the body, including the brain and heart. Traditionally, angiography was used to diagnose pathology of these vessels such as blockage caused by plaque build up. However in recent decades, radiologists, cardiologists and vascular surgeons have used the x-ray angiography procedure to guide minimally invasive surgery of the blood vessels and arteries of the heart. In the last several years, diagnostic vascular images are often made using MR, CT and/or ultrasound and while x-ray angiography is reserved for therapy. Conventional x-ray angiography has a lead role in the detection, diagnosis and treatment of heart disease, heart attack, acute stroke and vascular disease which can lead to stroke.

How Does Angiography Work

Angiographic x-ray imaging has grown into its own classification of x-ray imaging over time. The basic principal is the same as a conventional x-ray: x-rays are generated by an x-ray tube and as they pass through the body part being imaged; they are attenuated (weakened) at different levels. These differences in x-ray attenuation are then measured by an Image Intensifier and the resulting image is picked up by a TV camera. In modern angiography systems, each frame of the analog TV signal is then converted to a digital frame and stored by a computer in memory and/or on hard magnetic disk. These x-ray "movies" can be viewed in real time as the angiography is being performed, or they can be reviewed later using recall from digital memory.

During angiography, physicians inject streams of contrast agents or dyes into the area of interest using catheters to create detailed images of the blood vessels in real time. During the angiographic procedure, physicians can guide a catheter into the area of interest to remove stenoses (blockages) of blood vessels. Patients with blockages of the major leg vessels, for instance, can have nearly total recovery after angioplasty is performed to remove the constriction.

3.4 Computed Tomography (CT)

Computed Tomography (CT) imaging, also known as "CAT scanning" (Computed Axial Tomography), combines the use of a digital computer together with a rotating x-ray device to create detailed cross sectional images or "slices" of the different organs and body parts such as the lungs, liver, kidneys, pancreas, pelvis, extremities, brain, spine, and blood vessels. For many patients, CT can be performed on an outpatient basis without requiring admittance to the hospital.

Figure 3.1 Axial CT image of the liver and kidneys shows a benign (non-cancerous) cyst in the right kidney (arrow)

CT is one of the best tools for studying the lungs and abdomen. CT is an invaluable tool in the cancer diagnosis process and is often the preferred method for diagnosing lung, liver and pancreas cancer. CT imaging and CT angiography are finding a greater role in the detection, diagnosis and treatment of heart disease, acute stroke and vascular diseases which can lead to stroke, gangrene or kidney failure. Additionally, CT can be used to measure bone mineral density for the detection of osteoporosis. CT has excellent application in trauma cases and other emergencies. All dedicated shock-trauma centers have a CT scanner in the trauma department so patients can be immediately scanned to scout for major internal injuries such as aortic aneurysm (see image below) or other internal bleeding.

Computed Tomography is based on the x-ray principal: as x-rays pass through the body they are absorbed or attenuated (weakened) at differing levels creating a matrix or profile of x-ray beams of different strength. This x-ray profile is registered on film, thus creating an image. In the case of CT, the film is replaced by a banana shaped detector which measures the x-ray profile.

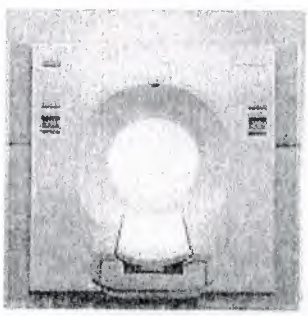


Figure 3.2

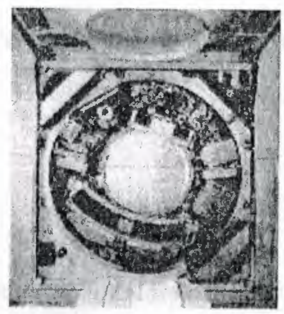


Figure 3.3

Figure 3.2 Outside view of modern CT system showing the patient table and CT scanning patient aperture

Figure 3.3 Inside view of modern CT system, the x-ray tube i s on the top at the 1 o'clock position and the arc-shaped CT detector is on the bottom at the 7 o'clock position. The frame holding the x-ray tube and detector rotate around the patient as the data is gathered

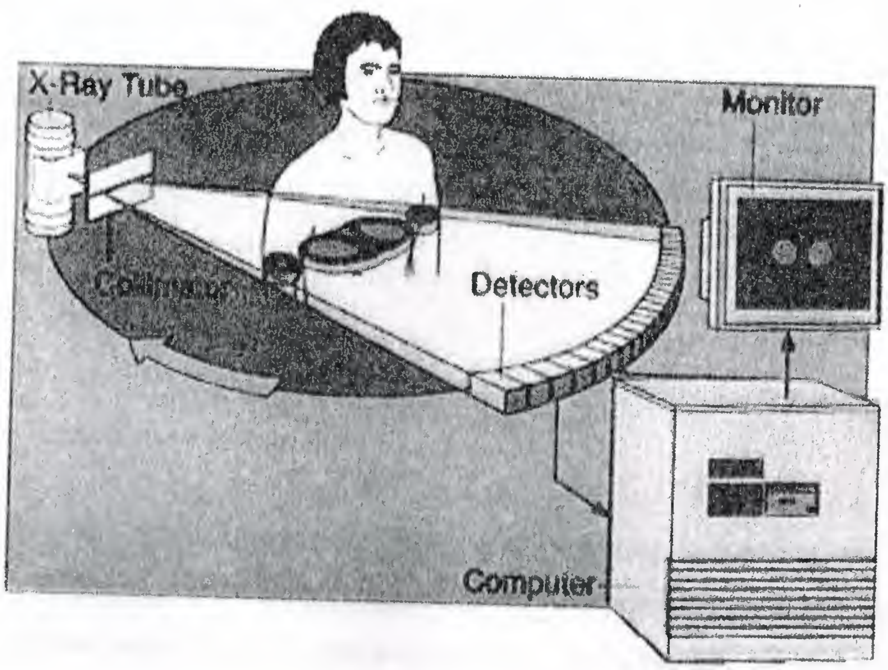


Figure 3.4 Diagram showing relationship of x-ray tube, patient, detector, and image reconstruction computer and display model

A CT scanner looks like a big, square doughnut. The patient aperture (opening) is 60 cm to 70 cm (24" to 28") in diameter. Inside the covers of the CT scanner is a rotating frame which has an x-ray tube mounted on one side and the banana shaped detector mounted on the opposite side. A fan beam of x-ray is created as the rotating frame spins the x-ray tube and detector around the patient (see figure below). Each time the x-ray tube and detector make a 360° rotation, an image or "slice" has been acquired. This "slice" is collimated (focused) to a thickness between 1 mm and 10 mm using lead shutters in front of the x-ray tube and x-ray detector. As the x-ray tube and detector make this 360° rotation, the detector takes numerous snapshots (called profiles) of the attenuated x-ray beam. Typically, in one 360° lap, about 1,000 profiles are sampled. Each profile is subdivided spatially (divided into partitions) by the detectors and fed into about 700 individual channels. Each profile is then backwards reconstructed (or "back projected") by a dedicated computer into a two-dimensional image of the "slice" that was scanned. Multiple computers are used to control the entire CT system. The main computer that orchestrates the operation of the entire system is called the "host computer." There is also a dedicated computer that reconstructs the "raw CT data" into an image. A workstation with a mouse, keyboard and other dedicated controls allows the technologist to control and monitor the exam. The CT gantry and table have multiple microprocessors that control the rotation of the gantry, movement of the table (up/down and in/out), tilting of the gantry for angled images, and other functions such as turning the x-ray beam on an off.

3.5 Magnetic Resonance Imaging

A benefit of MR is that, unlike conventional x-ray or CT imaging, it does not use x-ray radiation. Magnetic resonance imaging is non-invasive and provides exquisite images with excellent contrast detail of soft tissue and anatomic structures like gray and white matter in the brain or small metastatic lesions (cancers) in the liver. In comparison to MR, conventional x-ray provides images of dense structures like bones with good resolution. The x-ray angiogram is the traditional standard for imaging vessels like the carotid arteries in the neck, vessels in the brain, peripheral arm and leg vessels, or the coronary arteries which supply blood to the heart. But conventional angiographic imaging is very labor-and-time-intensive and requires administration of significant amounts of contrast to image the blood vessels. X-ray angiography does not provide good images of the soft tissue organs in the body like the liver or brain.

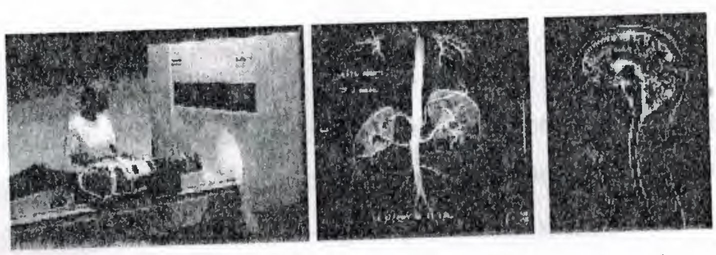


Figure 3.5 MRI machine, films of kidneys & brain.

The MRI machine applies an RF (radio frequency) pulse that is specific only to hydrogen. The system directs the pulse toward the area of the body we want to examine. The pulse causes the protons in that area to absorb the energy required making them spin, or process, in a different direction. This is the "resonance" part of MRI. The RF pulse forces them (only the one or two extra unmatched protons per million) to spin at a particular frequency, in a particular direction. The specific frequency of resonance is called the Larmour frequency and is calculated based on the particular tissue being imaged and the strength of the main magnetic field. These RF pulses are usually applied through a coil. MRI machines come with many different coils designed for different parts of the body: knees, shoulders, wrists, heads, necks and so on. These coils usually conform to the contour of the body part being imaged, or at least reside very close to it during the exam. At approximately the same time, the three gradient magnets jump into the act. They are arranged in such a manner inside the main magnet that when they are turned on and off very rapidly in a specific manner, they alter the main magnetic field on a very local level. What this means is that we can pick exactly which area we want a picture of. In MRI we speak of "slices." Think of a loaf of bread with slices as thin as a few millimeters -- the slices in MRI are that precise. We can "slice" any part of the body in any direction, giving us a huge advantage over any other imaging modality. That also means that you don't have to move for the machine to get an image from a different direction -- the machine can manipulate everything with the gradient magnets. When the RF pulse is turned off, the hydrogen protons begin to slowly (relatively speaking) return to their natural alignment within the magnetic field and release their excess stored energy. When they do this, they give off a signal that the coil now picks up and sends to the computer system. What the system receives is mathematical data that is converted, through the use of a Fourier transform, into a picture that we can put on film. That is the "imaging" part of MRI.

Visualization

Most imaging modalities use injectable contrast, or dyes, for certain procedures. MRI is no different. What is different is the type of contrast we use, how it works and why we use it. The contrast or dye materials used in X-ray and CT scan work in the same way because both areas use X-rays (ionizing radiation). These agents work by blocking the X-ray photons from passing through the area where they are located and reaching the X-ray film. This results in differing levels of density on the X-ray/CT film. These dyes have no direct physiologic impact on the tissue in the body. The contrast used in MRI is fundamentally different. MRI contrast works by altering the local magnetic field in the tissue being examined. Normal and abnormal tissue will respond differently to this slight alteration, giving us differing signals. These varied signals are transferred to the images, allowing us to visualize many different types of tissue abnormalities and disease processes better than we could without the contrast.

Understanding the Technology of Atoms

The human body is made up of untold billions of atoms, the fundamental building blocks of all matter. The nucleus of an atom spins, on an axis. You can think of the nucleus of an atom as a top spinning somewhere off its vertical axis.

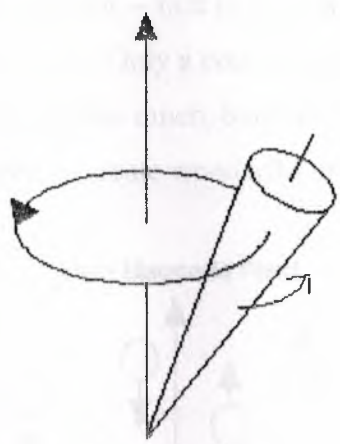


Figure 3.6 A top that is spinning slightly off the vertical axis is precessing about the vertical axis.

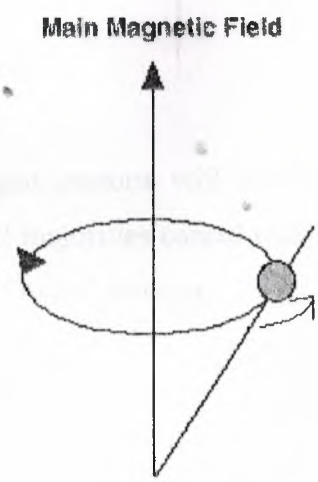


Figure 3.7 A hydrogen atom precesses about a magnetic field

Imagine billions of nuclei all randomly spinning or precessing in every direction. There are many different types of atoms in the body, but for the purposes of MRI, we are only concerned with the hydrogen atom. It is an ideal atom for MRI because its nucleus has a single proton and a large magnetic moment. The large magnetic moment means that, when placed in a magnetic field, the hydrogen atom has a strong tendency to line up with the direction of the magnetic field. Inside the bore of the scanner, the magnetic field runs straight down the center of the tube in which we place the patient. This means that if a patient is lying on his or her back in the scanner, the hydrogen protons in his or her body will line up in the direction of either the feet or the head. The vast majority of these protons will cancel each other out -- that is, for each one lined up toward the feet, one toward the head will cancel it out. Only a couple of protons out of every million are not canceled out. This doesn't sound like much, but the sheer number of hydrogen atoms in the body gives us what we need to create wonderful images.

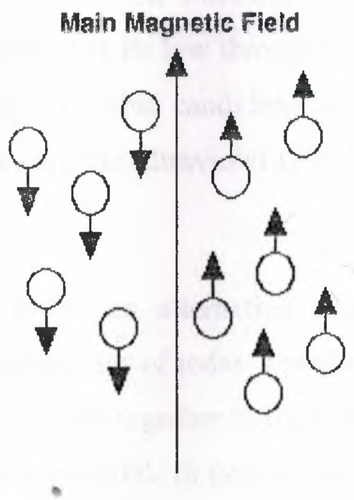


Figure 3.8 All of the hydrogen protons will align with the magnetic field in one direction or the other. The vast majorities cancel each other out, but, as shown here, in any sample there is one or two "extra" protons.

3.6 Applications of X-Rays for Preparation of Nanopatterned Surfaces.

The tremendous advances made by the microelectronics industry is recent decades can be attributed to the ability to pattern circuits with ever decreasing dimensions using modern lithographic techniques. In recent years the patterning techniques that were mainly developed for electronics applications have found applications in other areas of science and technology including life sciences, perhaps the best known of which are micro fluidic devices and DNA chips. Now we are entering the even more exciting regime of nano-scale patterning where devices and processes working at dimensions close to the molecular length scales are being investigated. Projection photolithography using visible and ultraviolet light has maintained its place as the main mass production technique. The spatial resolution in photolithography is limited by the wavelength of light. As we approach sub-100nm feature sizes, new lithography techniques are needed to overcome this limitation imposed by the wavelength. Electron beam lithography can pattern features smaller than 10nm but its low throughput limits its use to research and some niche production applications. Other candidates for the so called next generation lithography techniques include extreme ultraviolet (EUV) projection, x-rays proximity and nanoimprint techniques.

Interference lithography (IL) offers an alternative way to achieve high resolution patterning that is beyond the capabilities of today's production techniques. In IL two or more coherent light beams are brought together to form an interference pattern which is then recorded in a photosensitive material. In general the patterns achieved with IL are periodic; e.g. one-dimensional line/space patterns or two dimensional dot arrays are readily obtained. Lasers are commonly used as light sources in IL due to their coherent properties. We have recently extended the technique to the x-ray region where the extremely small wavelength has allowed us to achieve patterns with periods as small as 40nm. The theoretical limit for pattern period is equal to half of the wavelength, which is about 60nm in our system. The technique is based on the coherent light available from modern synchrotron sources. The main goals of the project are to produce patterns with sub 50nm periods, over areas as large as several mm2 with high throughput. Periodic patterns with nanometer scale resolution can be used to influence the growth of cells and tissues. Even though cells are often as big as tens or hundreds of micrometers, the processes and intracellular structures have much smaller length scales. There is growing evidence that through these processes high resolution surface patterns influence call growth behavior.

3.7 Assessment of Various Approaches to vertical Jump Testing of Sportsmen.

Introduction

The 60-seconds vertical jump test (VJT) as one of the physical fitness tests is used for evaluation of ergogenic anaerobic capacity of sportsmen. The test includes performing of one-minute non-stop consecutive maximal vertical jumps. During the test, the time of sportsman's contact with the platform and his flight time are usually measured by electronic equipment called ergo jump.

The flight time during each jump is recorded and power output is calculated in accordance with the formula below:

W=(9,8. Tf. 60)/4.N.(60 –Tf) ,

where W indicates mechanical power, 9,8 is normal acceleration of gravity, Tf is sum of total time of flight of all jumps and N is the number of jumps during 60 seconds.

The sportsman must jump continuously with maximal effort, with his knees bent to about 90 degrees and hands kept on his hips to minimize lateral and horizontal displacement. However, special requirements for proper completing of VJT, like 1) keeping balance during jumping or 2) allowing certain knee bending for jumping cannot always be met by examinees, which interferes with accuracy and reliability of the test. Besides, due to expensiveness of ergo jumps, the routine application of VJT for evaluation of physical fitness of sportsmen in many state schools and universities is not always possible. There are various simple and cheap applications of ergo jump techniques, which would allow routine evaluation of anaerobic capacity in all groups of sportsmen.

The experiences of cheap and simple ergo jump techniques are reported in the studies in the former USSR. These reports cover the following issues;

1- pneumatic jump power summing (i.e. integrating) system; gage- an inflating bulb, meter-integrator, an aneroid manometer with one-way airflow valve.

2-hydraulic-pneumatic jump power integrating system: gage-water filled elastic bulb-pump, meter-integrator—any manometer with air-compensator and one way water-flow valve;

3-electro-magnetic jump power integrating system: gage – a coil with moving permanent magnet core, meter-integrator, a diod, an electrolytic capacitor group and electronic voltmeter; Far more sophisticated jump power summing (integrating) system is based on:

4- different analog position or proximity sensors,

5- electrical resistance strain gages,

6- light emitting diods and light transistors,

7- piezo crystal gage, etc.

The first three approaches have been realized as pilot projects with satisfactory results. Due to necessity for their improvement, these projects are still under experimental trial. All other above mentioned approaches are cheaper than digital, but require computer connection to throw A-D interface for further signal processing.The approach and electric diagram are extremely simple. The electrical elements, which are used in the diagram of Fig. 3, can be easily found in any electrical-electronic rubbish of even jungle or bushmen village schools. The diagram Fig.3 mainly consists of a DC battery of 12-24 Volts, any resistance of 1M ohms, a capacitor form15 to 60 microfarad (V_{max}=16-60V), a voltmeter up to 10-20V, normally **"ON"** spring-type contact (mounted under jumping desk), simple manual connection-disconnecting (C-D) and discharging(D) switches and connecting wires.

Electrical-Electronics approaches to the simplest ergo jump technique construction

There are many ergo-jump technique constructions based on electromagnetic or electronic approaches, using both analog and digital sensors and outputs, etc. Most of them are expensive or very expensive not only for village schools, as it was mentioned above, but also for most settlements and small towns sportive organizations.

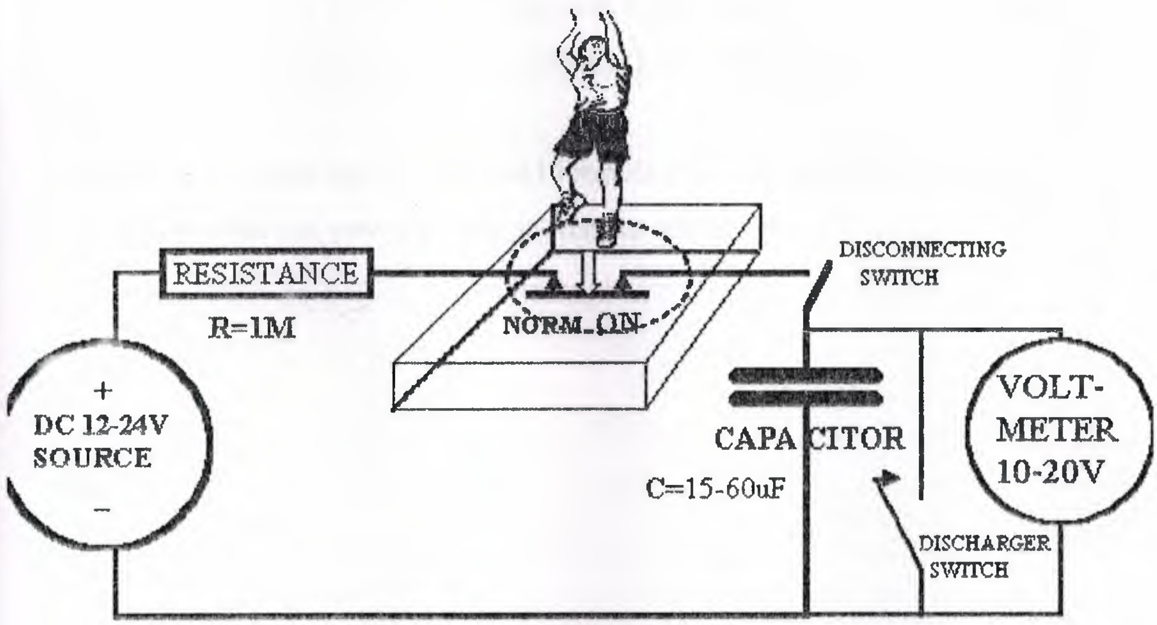


Figure 3.9 An electrical approach to ergo-jump meter construction.

The diagram works as the follows.

1. A sportsman stands on the jumping desk – the spring-type contact is **off** under his weight.

2. He or somebody switches **on** the C-D-switch discharges the capacitor for 3-5 seconds by D-switch.

3. The sportsman starts to jump during 60 seconds (15, 30, 45 depends on test) and counts N – number of jumps during 60 seconds.

4. At the end of test jump he or somebody switches **off** the C-D-switch and takes the voltmeter data V_{60} (or V_{15}, V_{30}, V_{45}).

5. The following simple equation can help to find Tf – sum of total flight time of all jump

$$\mathbf{T_f = -R*C*ln((V_{BAT} - V_{60}) / V_{BAT})}, \qquad (2)$$

Examples: $V_{BAT} = 12V$, $R = 10^6$ Ohms, $C = 15*10^{-6}$ F and

for $V_{60} = 10V$ $\quad T_f = - 10^6*60*10^{-6} \ln ((12-10)/12) = - 15* \ln (0.25) = 26.9sec$;

for $V_{60} = 9V$ $\quad T_f = - 10^6*60*10^{-6} \ln ((12-9)/12) = - 15* \ln (0.25) = 20.8$ sec;

for $V_{60} = 8V$ $\quad T_f = - 10^6*60*10^{-6} \ln ((12-8)/12) = - 15* \ln (0.333) = 16.5$ sec;

and so on.

6. Substituting Tf in the above mentioned formula (1) W = (9.8*Tf*60)/4N(60-Tf), the sought mechanical power for the sportsman can be found.

4. ELECTROCARDIOGRAPHY

4.1 Introduction

One of the main techniques for diagnosing heart disease is based on the electrocardiogram (ECG). The electrocardiograph or ECG machine permits deduction of many electrical and mechanical defects of the heart by measuring ECGs, which are potentials measured on the body surface. Wit an ECG machine, you can determine the heart rate and other cardiac parameters.

The basic objective of electrocardiograph can be seen By looking at electrical signals recorded only on the body surface, a completely noninvasive procedure, cardiologists attempt to determine the functional state of the heart. Although the ECG is an electrical signal, changes m the mechanical state of the heart lead to changes in how the electrical excitation spreads over the surface of the heart thereby changing the body surface ECG.

The study of cardiology is based on the recording of the ECGs of thousands of patients over many years and observing the relationships between various waveforms in the signal and different abnormalities. Thus clnical electrocardiography is largely empirical, based mostly on experiential knowledge. A cardiologist learns the meanings of the various parts of the ECG signal from experts who have learned from other experts.

4.2 Electrodes

As time went on, metallic electrodes were developed to electrically connect to the body. An electrolyte, usually composed of salt solution in a gel, forms the electrical interface between the metal electrode and the skin. In the body, movement of ions produces currents whereas in a wire, currents are due to the movement of electrons. Electrode systems do the conversion of ionic currents to electron currents.

Conductive metals such as nickel-plated brass are used as ECG electrodes but they have a problem. The two electrodes necessary to acquire an ECG together with the electrolyte and the salt-filled torso act like a battery. A dc-offset potential occurs across the electrodes that may be as large as or larger than the peak ECG signal. A charge double layer (positive and negative ions separated by a distance) occurs in the electrolyte.

Movement of the electrode such as that caused by motion of the patient disturbs this double layer and changes the dc offset Since this offset potential is amplified about 1, 000 times along with the ECG, small changes give rise to large baseline shifts in the output signal. An electrode that behaves in this way is called a polarizable electrode and is only useful for resting patients.

4.3 The Standard Limb Leads

Figure 4.1 shows how we can view the potential differences between the limbs as ideal voltage sources since we make each voltage measurement using an instrumentation amplifier with very high input impedance. It is clear that these three voltages form a closed measurement loop. From Kirchoffs voltage law, the sum of the voltages wound a loop equals zero. Thus

$$II-I-III=0$$

We can rewrite this equation to express any one of these leads in terms of two leads.

$$II=I+m$$

$$=II-rn$$

$$III=II-I$$

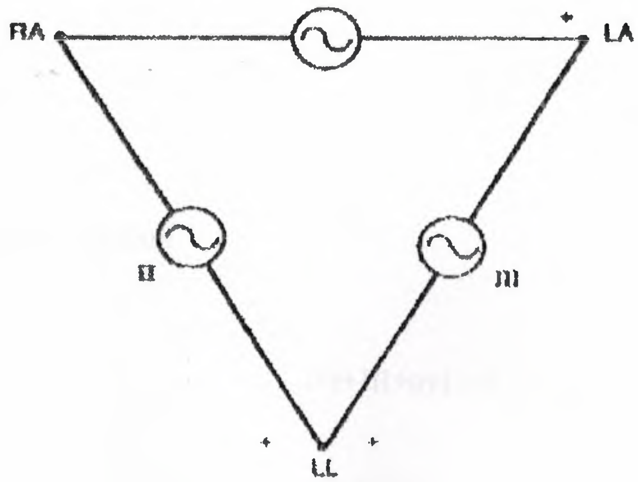


Figure 4.1 leads I, 114111 are the potential differences between the limbs and LA is the right and left arms AND LL is the left leg.

It is thus clear that one of these voltages is completely redundant; measure any two and compute the third in fact that is exactly what most machines do. Most machines measure leads I and II and compute lead might ask why we even bother with computing lead LII; it is redundant so new information not contained in leads I and II.

For the answer to this quest need to go back to Figure (4.1) and recall that cardiologists learned the relation between diseases and ECGs by looking at a standard set of leads and red appearance of each to different abnormalities. Since these three leads were in the beginning, the appearance of each of them is important to the cardiologists.

4.4 The Augmented Limb Leads

The early instrumentation had inadequate gain to produce large enough EC for all subjects, so the scheme in Figure 4.1 Was revised to produce large amplitude signals, the left arm signal (augmented limb lead as VL, is measured using the average of the potentials on the other two limbs as a reference, we can analyze this configuration using standard circuit theory, from the bottom left loop:

$$I * r + I * r - II = O$$

I*r=II /2

From the bottom right loop

-I*r+III+avL=0

Or aVL=I*rIII

Combining eqs gives

aVL=II/2-III= (II-2*III)/ 2

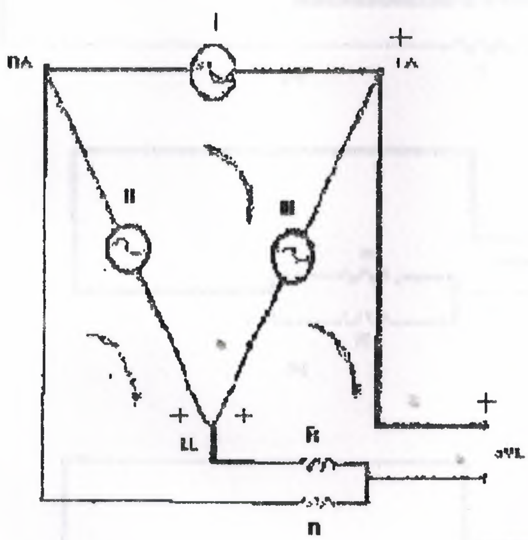


Figure 4.2 measuring the augmented limb lead aVL.

From the top center loop:

II=III+I

Substituting gives: aVL=(III+I-2*III)/2=(I-II)/2

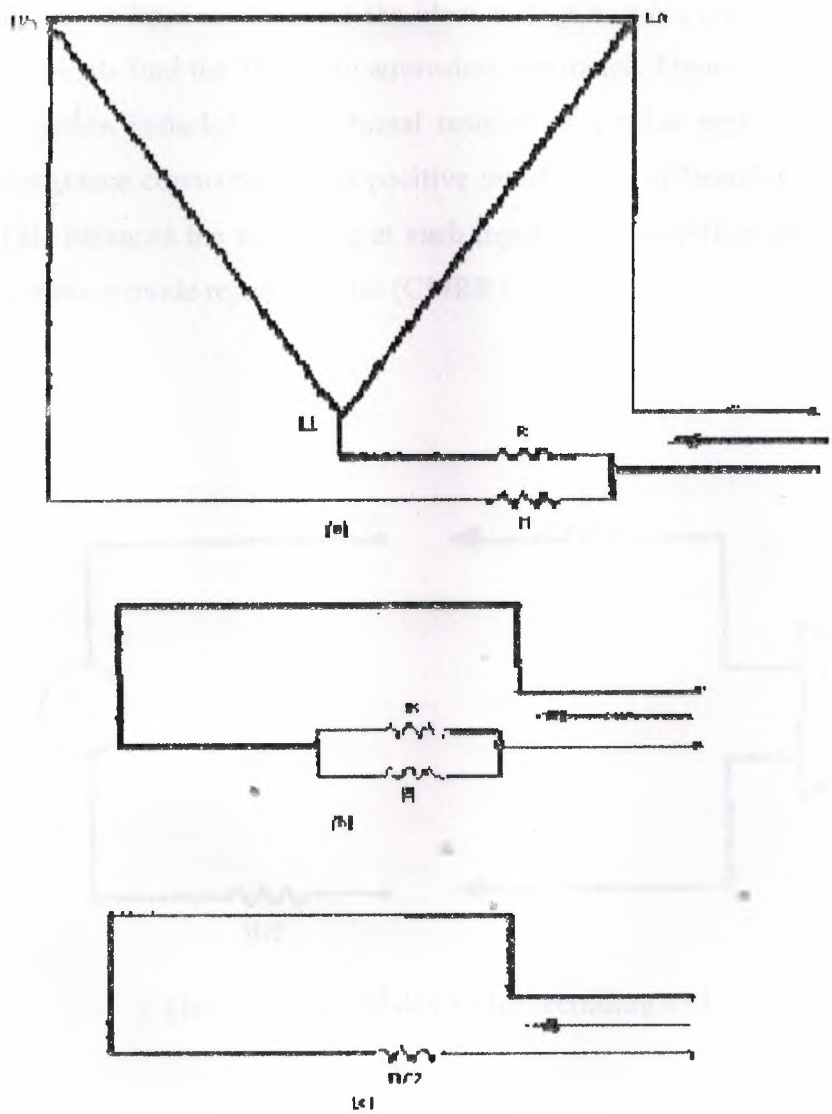


Figure 4.3 determination of the thevenin resistance for the aVL

This is the Thevenm equivalent voltage for the augmented lead aVL as an average of two of the frontal limb leads. It is clear that aVL is a redundant lead since it can be expressed in terms of two other leads. The other two augmented leads, aVR and aVF, similarly can both be expressed as functions of leads I and Ill. Thus here we find an additional three leads, all of which can be calculated from two of the frontal leads and thus are all redundant with no new real information. However due to the empirical nature of electro cardiology, the physician nonetheless still needs to see the appearance of these leads to facilitate the diagnosis.

Figure (4.3) Shows how shorting out the ideal voltage sources and looking back from the output terminals find the Th6venin equivalent resistance. Figure (4.4) illustrates that a recording system includes an additional resistor of a value equal to the Th6venin equivalent resistance connected to the positive input of the differential instrumentation amplifier. This balances the resistance at each input of the amplifier in order to ensure an optimal common mode rejection ratio (CMRR).

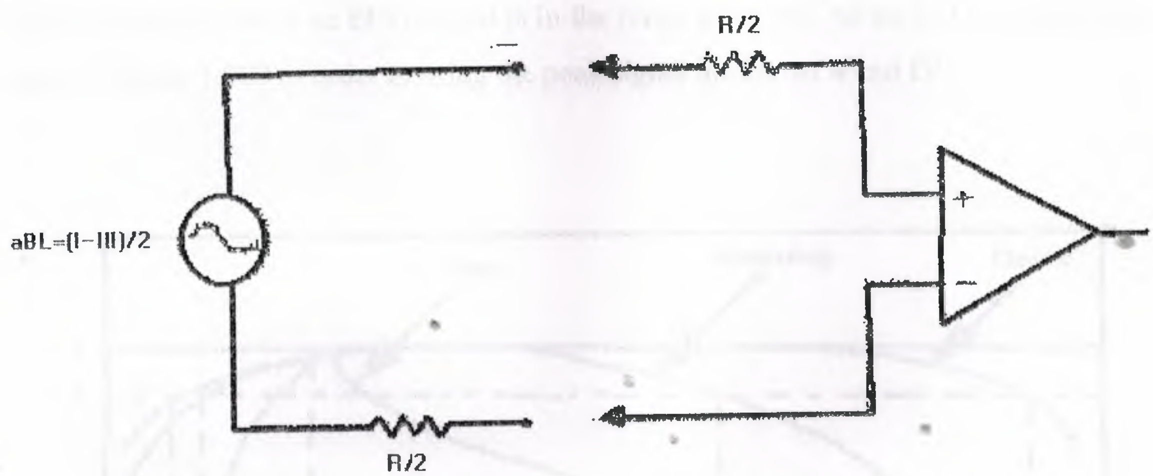


Figure 4.4 practical device for recording aVL.

4.5 ECG Signal Characteristics

Figure 4.5 shows three bandwidths used for different applications in electrocardiography (Tompkins and Webster, 1981). The clinical bandwidth used recording the standard 12-lead EGG is 0.05-100 Hz. For monitoring application such as for intensive care patients and for ambulatory patients, the bandwidth is striated to 0.5 - 50 Hz. In these environments, rhythm disturbances are principally of interest rather than subtle morphological changes in waveforms. Thus the restricted bandwidth attenuates. The higher frequency is caused by muscle contractions (electromyographic or EMG noise) and the low frequency noise caused by motion of the electrodes (baseline changes). An II bandwidth used for heart rate meters (card jotachometers) maximizes the signal noise ratio for detecting the QRS complex. Such a filter passes the frequencie's the QRS complex while rejecting noise including non-QRS waves in such as the P and T waves. This filter helps to detect the QRS complexes but torts the ECG so much that the appearance of the filtered signal is not clinically acceptable. One other application not shown extends the bandwidth up to 500 in order to measure late potentials. These are small higher-frequency in the ECG following the QRS complex.

The peak amplitude of an ECG signal is in the range of 1 mV, so an ECG typically has again of about 1,000 in order to bring the peak signal into ar. of about IV.

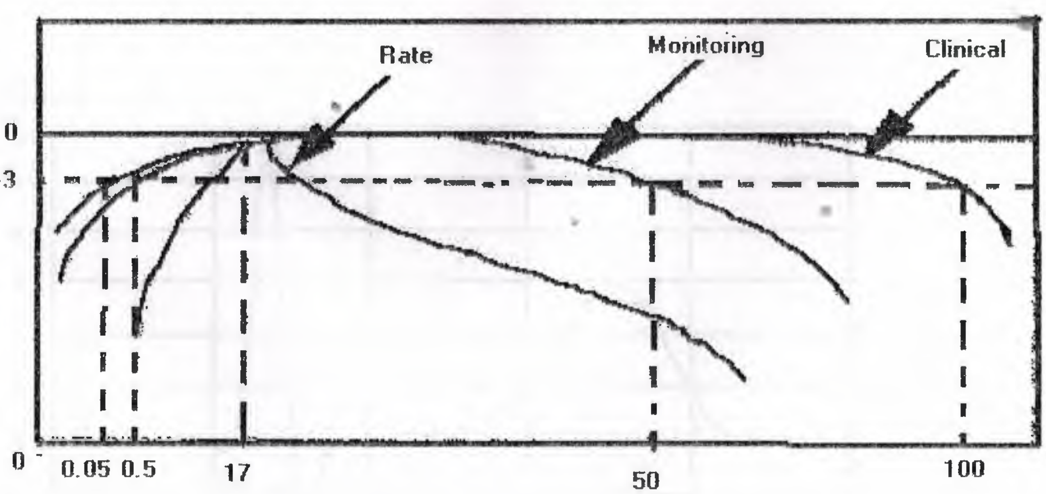


Figure 4.5 Bandwidths used for electrocardiography.

4.6 ECG Interpretation

This section covers the techniques for analysis and interpretation of the 12-lead ECG. Then it discusses ST-level analysis that is used in cardiac stress test systems. Finally, there is a summary of the hardware and software design of a portable ECG arrhythmia monitor.

Computer interpretation of the 12-lead ECG uses algorithms to determine whether a patient is normal or abnormal. It also provides written description of any abnormalities discovered.

Interpretation of the 12-lead ECG

ECG interpretation starts with feature extraction, which has two parts. The goals of this process are (1) waveform recognition to identify the waves in the ECG including the P and T waves and the QRS complex; and (2) measurement to quantify a set of amplitudes and time durations that is to be used to drive the interpretation process. Since the computer cannot analyze the ECG waveform image directly like the human eye-brain system, we must provide a relevant set of numbers on which it can operate.

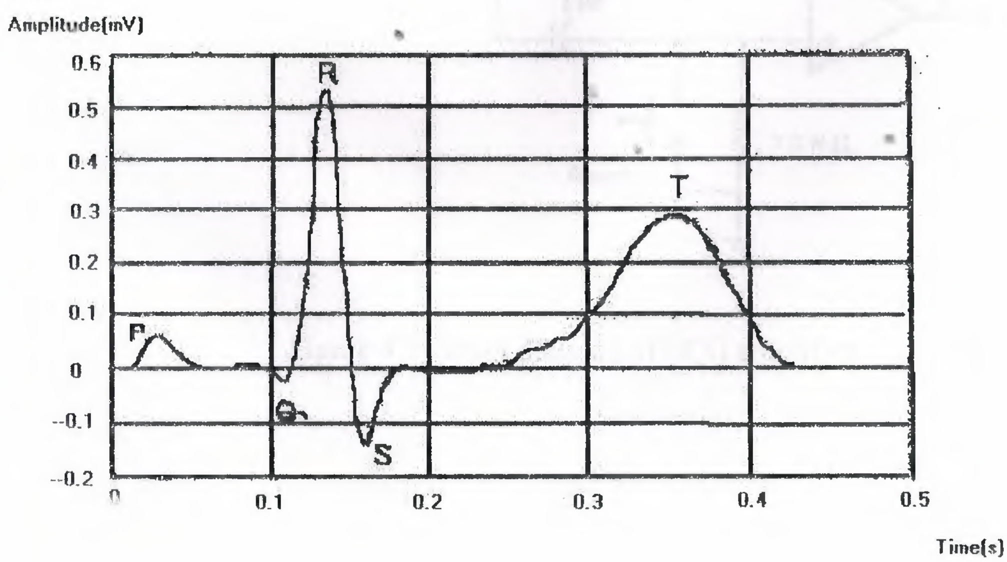


Figure 4.6 ECG for one normal heartbeat showing typical amplitudes and time durations for P. QRS, and T waves.

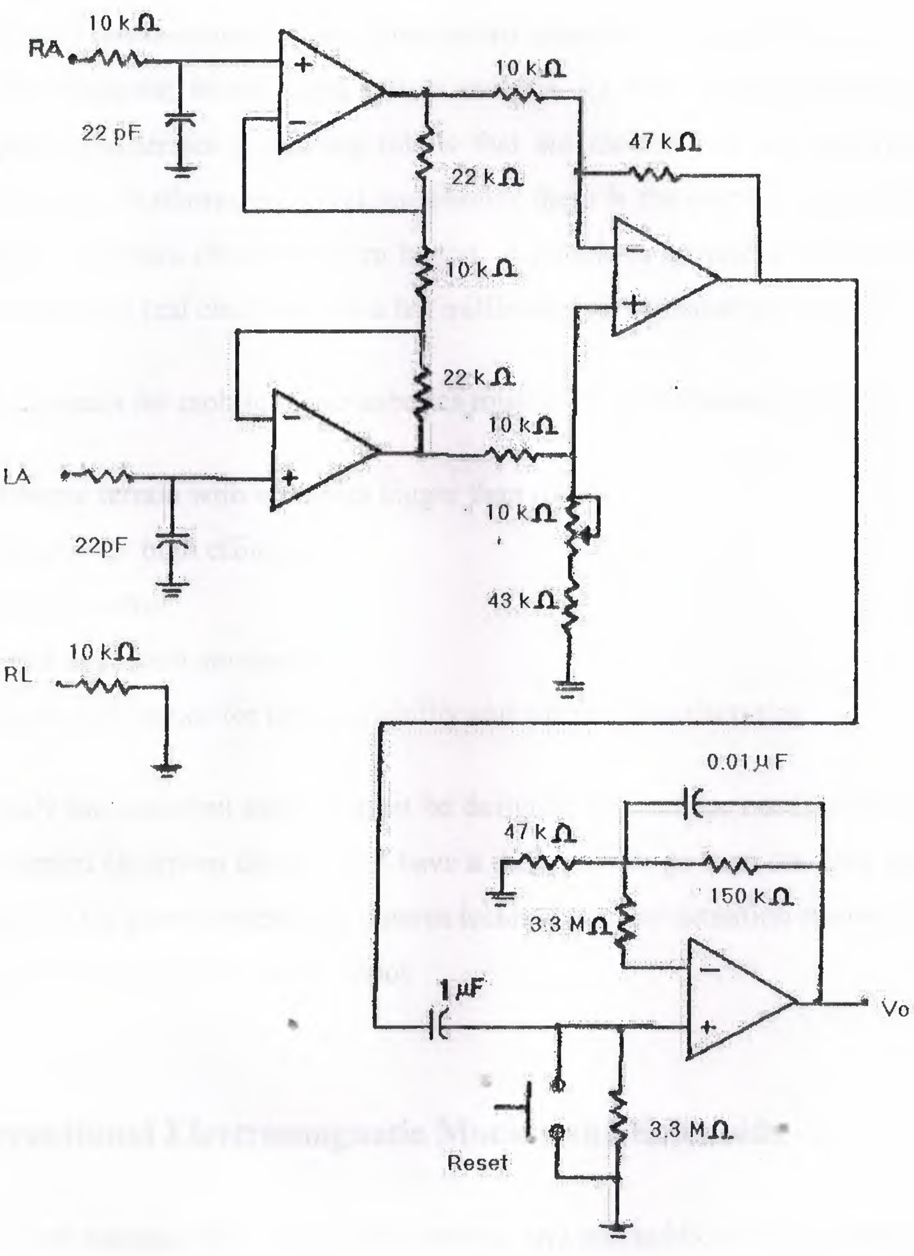


Figure 4.7 circuit diagram of ECG amplifier

5. Actuation for Mobile Micro-Robotics

5.1 Introduction

Advances in precision micro-machining have led to an interest in micro-robotics. Applications of micro-robotics range from micro-assembly, to biomedics (inner space), to land mine sweeping, to city water system analysis. As with conventional robotics one of the biggest challenges is making robots that are mobile and can traverse a wide variety of terrain. Furthermore, in micro-robotics there is the problem that as the robot gets smaller the terrain obstacles seem bigger. A pebble is no problem for a six meter long HMV, but it is real challenge for a ten millimeter surveillance robot.

Actuation systems for mobile micro-robotics must meet the following challenges:

- Traverse terrain with obstacles bigger than robot
- Low power/ high efficiency
- Simple control
- Withstand harsh environments
- Simple mechanics for both scalability and ease of manufacturing

Obviously the actuation method must be designed to meet the needs of the robot. A robot in a desert (scorpion design) will have a different design than one in a water pipe (fish design). This paper reviews the current technologies for actuation systems and then discusses some designs for a micro-robot.

5.2 Conventional Electromagnetic Motors and Solenoids

In the past robotics has mainly used motors and solenoids to make robots mobile. This can be done simply by using motors with wheels or tracks, or by using arms and legs powered by motors and solenoids. Designs of this type benefit from the large amounts of physical motion that can be produced. Furthermore, rolling motion like a car is very efficient and traverses simple terrain very well. The use of arms and legs adds the ability to traverse steps and other obstacles. However, electromagnetic motors are mechanically complex and do not scale down very well. Manufacturing electric motors less than a millimeter in size is very challenging. Other problems are power efficient (30-40% max.) and fragility.

5.3 Piezoelectric Linear Actuators

Piezoelectric materials are materials that expand/contract when an electric field is applied to them. They also will produce an electric field across themselves if a mechanical force is applied to them. Common places for piezoelectrics are in gas lighters, high frequency speakers, and micro-positioners. These devices rely on the piezoelectric effect. The piezoelectric effect happens in materials with an asymmetric crystal structure. When an external force is applied, the charge centers of the crystal structure separate creating electric charges on the surface of the crystal. This process is also reversible. Electric charges on the crystal will cause a mechanical deformation. Quartz, turmalin, and seignette are common natural piezoelectrics. Much work has gone into making polycrystalline ceramic piezoelectrics because physical properties can be tailored to the application. Furthermore, these materials can be bulk produced or deposited onto surfaces. Common ceramic piezoelectrics are lead-zirconate-titanate (PZT) and lead-magnesium-niobate (PMN). Piezoelectrics have also been made in polymer form, such as poly-vinylidene fluoride (PVDF).

Piezoelectrics deform linearly with applied electric field. Unfortunately, conventional materials only deform up to 0.1%. Thus, for a 5 cm leg on a micro-robot, the motion will be only 50 um. Furthermore, this happens at an electric field around 2 kV/mm. Thus, the applied voltage would have to be 100 kV. Piezoelectrics follow the equation

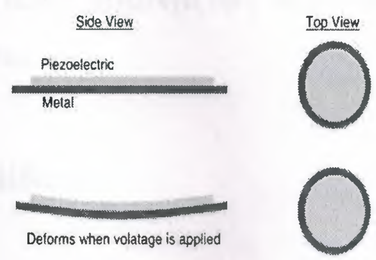
$$\Delta L = EdL_o + \frac{F}{C_T}$$

where E is the electric field, d is the piezoelectric tensor of the material, F is an externally applied force, and C_T is the stiffness of the material. Because strains are so small, piezoelectric actuators are mainly used in speakers or precision micro-positioning applications where small, precise motion is needed. However, deflection amplification methods make piezoelectrics possible actuators in micro-robotics.

5.4 Bending Mode Mechanical Amplifiers

When a voltage is applied across the ceramic and metal plate the unimorph bends. Reversing the voltage bends it in the other direction. This device relies on the d_{31} piezoelectric factor. This is the change in strain induced perpendicular to the electric field. The factor d_{31} is typically half of d_{33}, the induced normal to the electric field. However, a motion of 0.875 inches can be produced by a unimorph approximately one inch in diameter and 0.02 inch thick. This design is typically found in loud speakers.

Figure 1. Unimorph

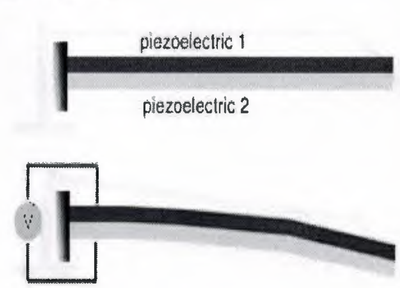


One amplification method is the unimorph design shown in figure 1.

Bimorph

Like the unimorph, the bimorph uses d31 piezoelectric actuation. The bimorph uses two piezoelectric plates that amplify the deflection as shown in figure 2. The two plates can be electrically connected in parallel or in series. A parallel connection produces twice the displacement as a series connection. In either case the strain is proportional to the square of the applied voltage.

Figure 2. Bimorph



RAINBOW

RAINBOWs or Reduced And Internally Biased Oxide Wafers are piezoelectric wafers with an additional heat treatment step to increase their mechanical displacements. In the RAINBOW process, developed by Gene Heartling at Clemson University, typical PZT wafers are lapped, placed a on graphite block, and heated in a furnace at 975 C for 1 hour. The heating process causes one side of the wafer to become chemically reduced. This reduced layer, approximately 1/3 of the wafer thickness, causes the wafer to have internal strains that shape the once flat wafer into a dome. The internal strains cause the material to have higher displacements and higher mechanical strength than a typical PZT wafer. RAINBOWs with 3 mm of displacements and 10 kg point loads have been reported.

5.5 Flextensional Amplifiers

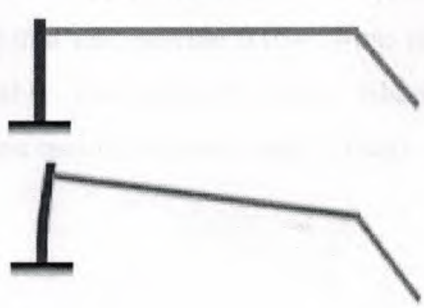
Stacks

Similar to the bimorph is the piezoelectric stack where several elements are placed on top of each other and electrically connected in parallel. The advantage of this design is that a stack uses the d33 which is larger than the d31 effect. Furthermore, displacements are N (number of elements in stack) greater for the same applied voltage.

Cantilevers

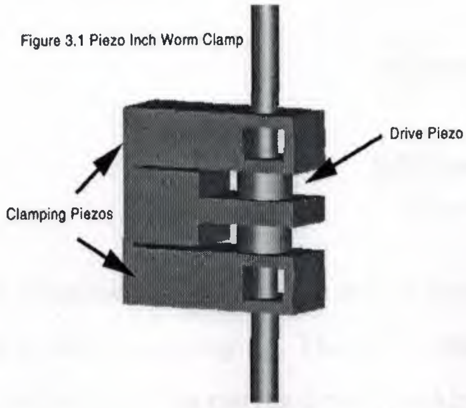
Other ways of producing mechanical amplification are through the use of cantilevers in figure 3. This is just a simple mechanical amplifier that increases displacement but reduces force.

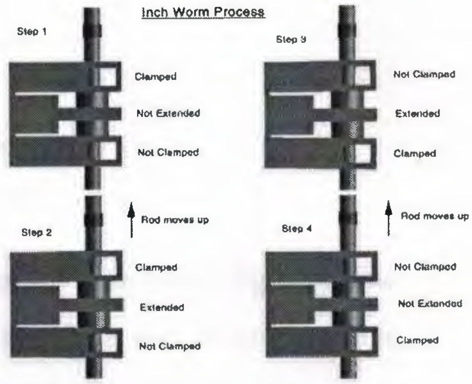
Figure 3. Cantilever Mechanical Amplification



Inch Worm Motors

Figure 3.1 Piezo Inch Worm Clamp



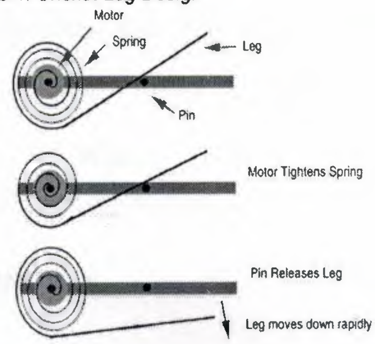


Piezoceramic inch worm motors are linear motors generally used in micro-positioning applications due to the ability to make very small accurate motions. The concept is shown in figures 3.1 and 3.2. There are two clamps and one extentional element. While clamp A is on and clamp B is off the drive piezo is extended. Then, clamp A is off and B is on returning clamp B to its original position by relaxing the drive piezo. Again, clamp A is on and clamp B is off the drive piezo is extended and so on. This is done many times and the rod moves up. Reversing the clamping sequence can make the rod move down. These devices can be operated at high frequencies to achieve millimeter per second motions. Some challenges of inch worm devices are achieving high precision in manufacturing so that the clamps work properly.

Piezoelectric Rotary Motors

Piezoelectric rotary motors have been developed that not only weigh much less than conventional electromagnetic motors but also supply much higher stall torque. Timothy S. Glenn and Nesbit W. Hagood at MIT have developed an 330 gram ultrasonic piezoelectric motor that can supply 170 N-cm. of torque[1]. A 8 mm, 0.26 gram motor has also been developed that can provide 0.054 N-cm of torque[2]. Piezoelectric rotary motors are also available commercially from Shinsei and Canon. Like other piezoelectric devices, these motors require a high voltage supply (~150 V).

Figure 4. Cricket Leg Design

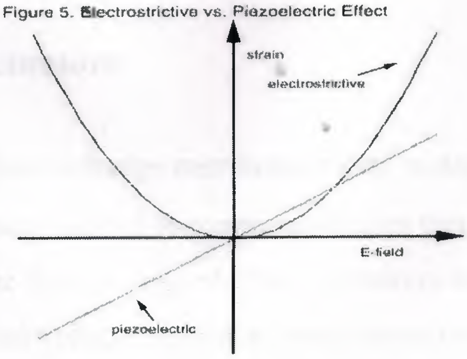


One possible actuator design with a piezoelectric rotary motor is shown in figure 4. The motor winds a spring up. The other end of the spring is held by a pin. When the pin is pulled back the leg moves down quickly and produces a "cricket" jumping motion.

5.6 Relaxor-ferroelectrics

Relaxor-ferroelectrics are similar to piezoelectrics except the strain is produced by the second order electrostrictive effect as opposed to the first order effect. The advantages of these actuators over conventional piezoelectrics include improved stroke (quadratic relationship to applied electric field shown in figure 5), low hysterisis, return to zero displacement when voltage is suddenly removed, and insusceptibility to stress depoling[3]. However, they have a higher temperature dependence of 65% change in expansion 0-50 C (only 5% for piezos).

Figure 5. Electrostrictive vs. Piezoelectric Effect



All insulators are electrostrictive and produce a strain under an applied electric field. While this effect is negligible in most materials, the PMN-PT-BT relaxor-ferroelectric manufactured by Lockheed Missiles and Space Company had a 0.1% strain at 1 kV/mm.

5.7 Magnetostrictive Actuators

Like the Piezoelectric effect where the material deforms under an applied electric filed, a magnetostrictive material deforms in a magnetic field. Induced strains and maximum stresses are on the same order of magnitude as piezoelectrics. One common magnetostrictive material TERFENOL (TER (Terbium) FE (Iron) NOL Naval Ordinance Laboratory)) produces a 0.2% strain in a 100 kA/m field. One major disadvantage of magnetostrictive actuators is the need for a device to produce the magnetic fields. This device is typically a coil wrapped around the material. This makes the device bulky and losses in the coils can be high.

5.8 Hybrid Actuators

Because piezoelectrics are capacitive and magnetstricters are inductive, delivering high electrical power to them individually can be inefficient and/or require matching networks. Even with with matching networks, high efficiency over a wide frequency range is difficult. However, recent work has been done using the two devices together in order to increase frequency operation.

5.9 Ion Exchange Actuators

The theory behind ion-exchange-membrane-metal composites is fairly complex. Essentially the materials are made of ionizable molecules that can dissociate and attain a net charge when a electric field is applied. These actuators have a large deformation in the presence of low applied voltage. Actuators made from these materials can deform as much as 2.5 cm under a 7 V applied voltage. These actuators best work in a humid environment, but may be encapsulated.

Shape Memory Alloys

Shape memory alloys are metals that deform when electric current is passed through them. The deformation is due to thermal expansion.

5.10 Robotics in surgery.

The use of information and robotics technologies provided many advances in the field of surgery. Today surgery has the capability of realizing our dreams. NASA is now working on a project that enables an astronaut to have a surgical operation in space. Still robotics systems are only at the beginning of their lifecycle. All these show the use of robotics technologies is only limited by surgeons' imagination and engineers' skills.

Surgery and Information Age

Today, there are three types of surgical operation techniques. The first one is the traditional data flow model, in which the surgeon directly contacts with the patient and sensorial inputs are synchronized. The second type, called the Laparoscopic surgery, or Keyhole surgery, is performed through ports which enable to view area in a video screen. A camera that passes through one port should be held by a surgeon or a robotic arm. This arm is controlled by the operating surgeon for visualization. In the last one, the surgeon is outside the operating room. Patients input and surgeons output are all electronically conducted by the help of robotic technology.

Robotic surgery

Robotics is a rapidly developing technology that requires close collaboration between engineers and surgeons. In fact, the term robotics should be called Master slave manipulator or Computer enhanced telemanipulator since machines act as remote extensions of the surgeon. The aim of robotics is not to replace the surgeon but to assist and enhance their skills. The robotics offers surgeons instant ambidexterity, much greater magnification than surgical loupes, additional movement, and the ability to tie sutures with only several inches of suture material. Now, robotic surgery applies more than 100 hospitals. There are two most popular systems: da Vinci Robotic Surgical System (Intuitive Surgical, Mountain View, Calif.) and ZEUS Robotic System (Computer Motion, Goleta, Calif.) Both of them have FDA approval for various procedures.

Telesurgery

Telesurgery is an application of telemedicine in which a surgeon at distance performs the operation by manipulating the hands of a robot by consulting a surgeon at operation site. The world's first transoceanic surgery performed in 2001, September 7 by Gagner, who was assisted by French surgeon Jacques Marescaux. The operation was named Operation Lindbergh, took 55 minutes. The first operation was chosen to be cholecystectomy because of its comparable low risks. The researchers used the ZEUS Robotic surgical system. Gagner and Marescaux used control panels in New York and manipulated 3 robotic arms--- 1 for providing close-up views and the other 2 for filling the surgeon's hands. The surgeons were linked to France by a secure fiber optic line. The transmission delay has been only 66 milliseconds.

5.11 Sensors And Transducers

Measurement systems

The amount of confidence in the results of a measurement is greatly increased when all factors influencing the measurement are fully understood. This requires a detailed knowledge of the measurement process and the possible interactions of the measurement process on the system being measured. These interactions can come from direct physical influences as well as biochemical, physiological, and psychological interactions with the measuring process. A measuring system is required to compare a quantity with a standard or to provide an output that can be related to the quantity being measured. The quantity to be measured is detected by the input transducer or sensor.
The detected quantity may be converted to a mechanical form or electrical form of energy. For most biomedical purposes, the form is electrical.

Because sensors and transducers are so broad and widely used, it is impossible to pinpoint the first invention. They have been around since the beginning of time. All life forms use sensors and transducers. For example, the eyes sense a stimulus from the environment and send it to the brain to be processed. Even a simple invention from many years ago such as the wind vane (tells which direction the wind is blowing) can be considered a sensor. It is only since the developments in microprocessor technology that digital transducers have become important and useful.

What are Sensors and Transducers

The words sensor and transducer are both used in referring to measurement systems.
Sensor is derived from the word sentire meaning to perceive whereas transducer is from transducer meaning to lead across. To distinguish between the two, a sensor is a device that detects a change in a physical stimulus and turns it into a signal which can be measured or recorded, and a transducer is a device that transfers power from one system to another in the same or in a different form. Normally, the sensor is just the sensing element itself and the transducer is the sensing element plus any associated circuitry.
Sensors and transducers may sense either analog or digital signals. An analog signal is a continuous measurable quantity, and a digital signal is a quantity that is sampled at fixed intervals. A higher sampling rate increases the accuracy of measurement. Because the human body produces analog signals, analog-to-digital converters are required in measuring with digital sensors.

Classification of Sensors and Transducers

Sensors and transducers must be classified according to the physical property that they use (piezoelectric, photovoltaic, etc.) or according to the function that they perform (measurement of length, temperature, etc.). Since energy conversion is an essential characteristic of the sensing process, the various forms of energy should be considered.
The following table lists the main forms of energy and their occurrence:

Type of energy	Occurrence
Radiant	Radio waves, visible light, infrared
Gravitational	Gravitational attraction
Mechanical	Motion, displacement; forces
Thermal	Kinetic energy of atoms and molecules
Electrical	Electric fields, currents
Magnetic	Magnetic fields
Molecular	Binding energy in molecules
Atomic	Forces between nucleus and electrons
Nuclear	Binding energy between nuclei
Mass energy	Energy given by E=mc^2

All of the above forms may be applied to biomedical measurements. For measurement purposes, six types of signals are important: radiant mechanical, thermal, electrical, magnetic, and chemical. The signal is fed into an input transducer, which changes the form of energy, usually into electrical. A modifier, usually an amplifier and an output transducer then convert the energy into a form to be displayed or recorded.

Three basic types of transducers are the self-generating, modulating and modifying transducers. The self-generating type (thermocouples, piezoelectric, photovoltaic) does not require the application of external energy. Modulating transducers (photoconductive cells, thermistors, resistive displacement devices) do require a source of energy. For example, a thermocouple is self-generating, producing a change in resistance in response to a temperature difference, whereas a photoconductive cell is modulating because it requires energy. The modifying transducer (elastic beams, diaphragms) is characterized by the same form of energy at the input and output. The energy form cm both sides of a modifier is electrical.

Why Do We Need Biomedical Sensors and Transducers?

The engineering profession has little room for improvement without measurements. An engineer must know the output of a measurand before he or she can manipulate it for a given purpose. Many years ago, people dealt with rulers and protractors to perfect geometry in structures. Today, advancements in technology have allowed measurements of complex systems that people previously thought were impossible. By the use of sensors and transducers, the properties of a system can be measured by observing the change in the properties of another. For example, the absorption of ultraviolet light in some chemical compounds can be measured by directing a given spectrum of light into a compound and measuring the amount of light transmitted on the other side with respect to its wavelength. The sensor provides this measurement, and the transducer converts it to an electrical signal that is representative of the measurement. From this signal, a computer can tell which wavelengths of light are absorbed and which are transmitted, also taking into account the reflected light. So why do we need these things? We do not need them for survival, but, for continuing improvement in technology, biosensors and transducers are a must. They allow us to measure useful entities such as the voltage across the heart, brain activity, and the presence of foreign compounds in the blood. From these measurements, physicians can prescribe treatments and detect abnormalities, and engineers can develop devices to correct abnormalities such as the pacemaker and defibrillator. Transducers and biosensors unveil the great curtain that masks the secrets of our bodily functions. For example, by measuring the voltage across the heart, we have developed a graph of the voltage with respect to time, called the electrocardiogram (ECG) that is common for normal sinus heart rhythm in most people. Any change in the voltage pattern is representative of a problem such a ventricular fibrillation or heart flutters. The possibilities are limitless. Any abnormality that causes a change in a measurable property opens the pathway for new transducers and biosensors.

Examples of Modern Biomedical Sensors and Transducers

In Vivo Measurement of Dye Concentration Using an Evanescent Wave Optical sensor. This sensor is designed far in vivo measurement of dye concentrations. Dye may be used for a number of purposes, usually to detect the presence of a chemical substance in the blood. This sensor, constructed with polished fibers, allows continuous monitoring of the florescent spectra between 380 and 650 nm. The dimensions of the sensor probe allow insertion into hypodermic needles for spectroscopic analysis of tissues and blood.

A Transcutaneous Blood Constituent Monitoring Method Using a Suction Effusion Fluid Collection Technique and Ion-Sensitive Field-Effect Transistor Glucose Sensor: This sensor allows nortinvasive, transcutaneous monitoring of low molecular weight substances in the blood without ordinary blood sampling. It has been effectively used to measure glucose levels in humans. Such a sensor opens the possibility of disease detection without the use of needles to withdraw blood.

Etectrocatalytic Glucose Sensor

This sensor is a flowthrough cell with three electrodes that can be integrated into a blood vessel. The measurement principle is based on the electrochemical oxidation of glucose at a membrane-covered noble-metal electrode. Noninvasive Measurement of Blood Glucose Concentrations by Analyzing Fourier Transform Infrared Absorbance Spectra through Oral Mucosa: This experiment involved the evaluation of whether Fourier transforms infrared spectroscopy x4ith an attenuated total reflection prism could be applied for noninvasive glucose measurement through oral mucosa. The results showed the same absorbance peak at 1033 cm' in glucose aqueous solution as in the absorbance spectra through mucus membrane. The noninvasive measurement of glucose in blood could be useful for diabetes patients. Optical Oxygen Sensor Based on Phosphorescence Lifetime Quenching and Employing a Polymer immobilized Metalloporphyrin Probe: Continuous monitoring of the respiratory gases (oxygen and carbon dioxide) is a common procedure in the medical field. It is used for the study of respiration, assistance in anesthesiology, and treatment and diagnosis of cardiopulmonary disorders. Such a sensor is useful in monitoring these gases, simple, noninvasive System for Measuring the Heart Rate of Avian Embryos and Hatchlings by Means of a Piezoelectric Film.

The minute movement of the incubated avian egg is produced by atrial and ventricular contractions as well as blood ejection to the aorta. To measure the heart rate of a newly hatched bird noninvasively, researchers used a flexible piezoelectric film that detected precordial movements of hatchlings comparable to their cardiac contractions. This is referred to as the apexcardiogram (ACG).

Laser Photoacoustic Determination of Physiological Glucose Concentrations in Human Whole Blood

A spectroscopic technique, based on photoacoustic spectroscopy, is used to determine the glucose concentration in human whole blood. The device uses a carbon dioxide laser operating with microjoule pulse energies. The sensitivity of this system is comparable with existing commercial enzyme-based diagnostic systems presently used in hospitals.

Pulse Oximetry: Theoretical and Experimental Models

The pulse oximeter is a noninvasive optical instrument that measures arterial oxygen saturation in a pulsatile vascular bed. The optical properties of blood are measured as a function of cuvette depth by transmission spectrophotometry using red and infrared light-emitting diodes as light sources.

Monitoring of Respiratory and Heart Rates Using a FibreOptic Sensor results from the use of a new fiber optic probe to monitor respiratory and heart rates provide evidence that respiratory and heart rates can be monitored using the reflection mode of photoplethysmography (PPG). The patient can be monitored from different sites, and the method is convenient. The probe is also X-ray transparent, insensitive to electromagnetic interference and may be made very light and small.

Fast Responding Automated Airway Temperature Probe:

The purpose of this project was to build a temperature-measuring system to be placed into the airways of airway diseased patients while they were exercising. The result was a device that could be used to monitor the thermal transients, which are seen in the airways of asthmatic patients as their airways rewarm following hyperpnoea.

6. ELECTRICAL SAFETY

It is not surprising that incidents of accidental electric shock have been on the increase, since the number and variety of household and industrial electrical devices have proliferated. In perspective, however, we can see that the safety record fix users of electrical energy are undoubtedly better than for users of fossil fuels.

Electronic instrumentation for medical practice has also increased greatly in quantity and complexity during the past few decades. Unfortunately, we encounter some special shock hazards because some of these instruments are connected to patients in ways that bypass the body's normal defenses. Early in 1969 there were reports those currents well below normal perceptual levels could electrocute some catheterized patients. The safety scare that followed reached a peak in about 1971, when Ralph Nadir (1971) and Carl Walter (1970) claimed that each year 1200 Americans were electrocuted during routine diagnostic and therapeutic procedures. This figure was not and cannot be documented, because there is seldom-pathological evidence for these electrocutions.

Although the furor caused some unnecessary actions to be taken, the knowledge of electrical hazards gained and the protection now incorporated into electronic instruments have eliminated many of the hazards and reduced the fears. Now, with proper training for personnel, modem equipment, and regular testing procedures, hospitals can minimize the risk of accidental electric shock. As new instruments and medical procedures are introduced, we must consider potential electrical safety hazards.

In this final chapter we shall discuss the physiological effects of electric current shock hazards, methods of protection, and electrical testing procedures. One objective is to learn bow to incorporate safety features into the design of medical instruments studied in previous chapters.

Electrical safety in the broadest sense involves more than electric shock For example, lead breakage on cardiac monitors or electrocute units is detrimental to patient care. Line voltage variations can cause some Infant apnea monitors to erroneously indicate proper respiration. Electrical interference can cause incorrect cardio tachometer readings. Slight leakage of electrical insulation in thermistors can cause errors in temperature measurements.

6.1 Physiological Effects of Electricity

For a physiological effect to occur, the body must become of an electric circuit. Current must enter the body at one point leave at some other point. The magnitude of the current is equal the applied voltage divided by the impedance of the body and contact interfaces between the two areas of contact. Three general effects can occur when electric current flows through biological tissue: (I) resistive heating of tissue, (2) electrical stimulation at excitable tissue (nerve and muscle), and (3) electrochemical (for direct current).

Let us now discuss psychophysical and physiological effects humans in the order that these effects occur for increasing current, the approximate range of currents that produce each effect in a 70-kg man for 1- to 3-s expose. To 60-Hz current applied to the hands. Susceptibility parameters for variations in these conditions are considered.

Threshold of Perception

For the conditions just stated, when the local current density is large enough to excite nerve endings in the skin, the subject feels- a tingling sensation. The threshold of perception is the minimum current that an individual can detect. This threshold varies considerably among individuals, and according to the measurement conditions: When someone with moistened hands grasps small copper to 10 mA, and slight warming of the skin is perceived.

Let-go current

For higher levels of current, nerves and muscles are vigorously stimulated, eventually resulting in pain and fatigue. Involuntary contractions of muscles or reflex withdrawals by a subject experiencing any current above threshold may cause secondary physical injuries, such as falling. As the current increases further, the involuntary contractions of the muscles can prevent the subject from voluntarily withdrawing. The let-go current is defined as the maximum current for which the subject can withdraw voluntarily. For men, the percentile for the let-go current threshold is 9.5 A.

Respiratory Paralysis, Pain & Fatigue

Still higher currents cause involuntary contraction of respiratory muscles severe enough to cause asphyxiation if the current is not interrupted. During let go experiments, Dalzial (1973) observed respiratory arrest at 18-22 mA. Strong involuntary contractions of the muscles and stimulation of the nerves can be painful and cause fatigue if there is long exposure

Ventricular Fibrillation

The heart is susceptible to electric current in a special way that is particularly dangerous, Part of the current passing through the chest flows through the heart. If the magnitude of the current is sufficient to excite only part of the heart muscles, then the normal propagation of electrical activity in the heart muscle is disrupted, once the activity in the ventricles is desynchronized, the pumping action of the heart ceases and death occurs with in minutes.

This desynchronization of cardiac muscle tissue is called fibrillation. Unfortunately it doesn't stop when the current that triggered is removed. Ventricular fibrillation is the major cause of death due to electrical shock. The threshold for VF for an average sized man varies from 75-400 mA. Normal rhythmic activity will return only if a brief high current pulse from a defibrillator is applied to simultaneously depolarize all the cells of the heart muscle. Alter all the cells relax together, a normal rhythm usually returns.

Sustained myocardial contraction

When the current is high enough, the entire heart muscles contract. Although the heart stops beating while the current is applied, the normal rhythm ensues when the current is interrupted, just as in defibrillation Data from ac-defibrillation experiments on animals show that minimum currents for complete myocardial contraction are in the range from 1 to 6 A. No irreversible damage the heart is known to result from these currents.

Burns and physical injury

Very little is known of the effects of currents in excess of 10 A, particularly for currents of short duration. Resistive heating causes burns, usually on the skin at the entry points, because skin resistance is high. Voltages greater than 240 V can puncture the skin. The brain and other nervous tissue lose all functional excitability when high currents are passed trough them. Also, excessive currents may force muscular contractions that are strong enough top1 the muscle attachment away from the bone.

6.2 Important Susceptibility Parameters

The physiological effects previously described are fix an average 70-kg man and for 60Hz. Current applied for 1 to 3 s to moistened hands grasping a No. 8 copper wire. The current needed to produce each effect depends on all these conditions, as explained below. Minimal rather than average values are often most important for safety considerations.

Threshold and let-go variability

For men, the mean value for the threshold of perception is 1.1 mA for women; the estimated mean is 0.7 mA. The minimum threshold of perception is 500 ptA.

Let-go currents also appear to follow Gaussian distributions, with mean let-go currents of 16 mA for men and 10.5 mA for women. The minimum threshold let-go current is 9.5 mA for men and 6 mA for women. Note that the standard deviation for let-go current is much greater than the standard deviation for threshold-of-perception currents.

Frequency

A plot of let-go currents versus the frequency of the current. Unfortunately, the minimum let-go currents occur for commercial power-line frequencies of 50 to 60 Hz. For frequencies below 10 Hz, let-go currents rise, probably because the muscles can partially relax during part of each cycle. And at frequencies above several hundred hertz, the let-go currents rise, perhaps because of the well-known strength-duration trade off, and the refractoriness of excitable tissue.

Duration

Fibrillating-current thresholds for animals increase sharply for shocks that last less than about 1 s. The heart is known to be more vulnerable to fibrillation during about 100 ms of the heart cycle that corresponds approximately to the T wave in the EGG. Shocks of short duration, applied during other parts of the heart cycle, have much higher fibrillation thresholds.

Body weight

Several studies using various sizes of animals show that the Fibrillation threshold increases with body weight. However, there is considerable scatter in the data, even for dogs only also demonstrate the dependence of fibrillating current on body weight. These findings deserve more studies. Because they are used to extrapolate fibrillating currents for humans.

Points of entry

When current is applied at two points on the surface of the body, only a small fraction of the total current flows through the heart. These large externally applied currents are called macro shocks. The magnitude of current fibrillate the heart is far greater when the current is applied the surface of the body than it would be if the current were applied directly to the heart. The importance of the location for the two-macroshock entry points is often overlooked. If the two points are both on the same extremity, the risk of fibrillation is small, even fix high currents Geodes (1973) showed that for dogs, the current needed for fibrillation is greater for FCG lead I (LA-RA) electrodes than for ECG leads II and III (LL-RA, LL-LA). Protection afforded by the skin resistance (15 k to 1 Mf/cm2) is eliminated by many medical procedures that require insertion of conductive devices into natural openings or incisions in the skin, if the skin resistance is bypassed; less voltage is required to produce sufficient current for each physiological effect.

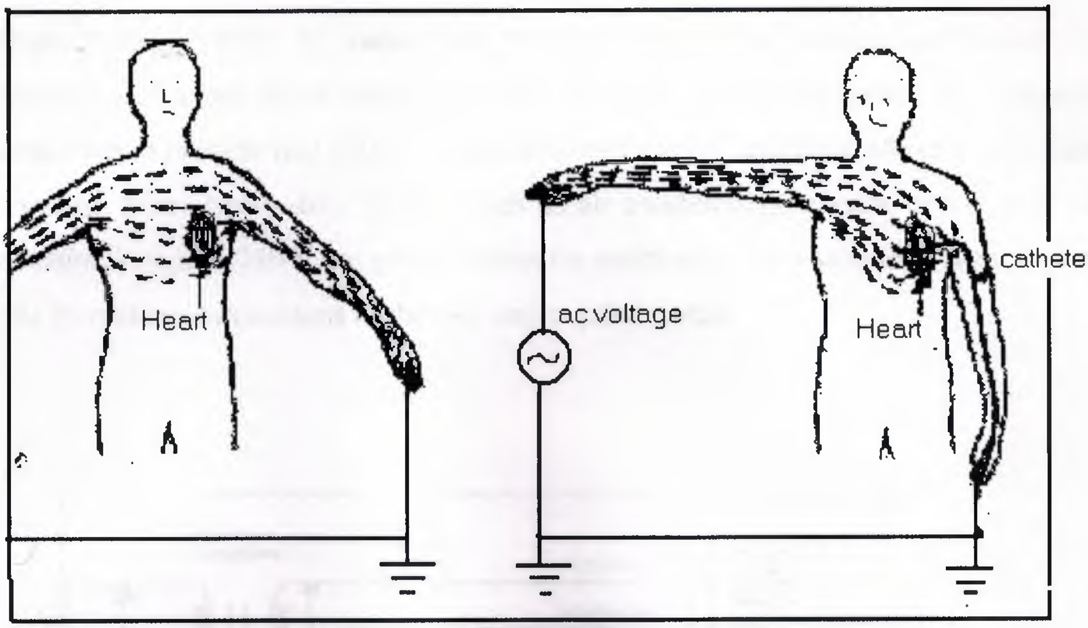


Figure 6.1 Effects of entry points on current distribution

Macro shock and micro shock.

Patients are particularly susceptible when devices are placed into or near the heart. A device is especially hazardous if it provides a conductive path from outside the body to a point on & within the heart, and if this conductor is insulated from the body except at the tip near the heart. All the current flowing through such a conductive device flows through.

6.3 Distribution of electric power

Electric power is needed in health-care facilities not only to operate medical instruments, but also for lighting, maintenance appliances, patent conveniences (such as TV, hair curlers, and electric toothbrushes), clocks, nurse call buttons, and an endless list of other electrical devices. A first step in providing electrical safety is to control the availability of electric power and grounds in the patients' environment. This section is concerned with methods for safe distribution of power in health-care facilities. Let us consider this material before we discuss various macro shock and micro shock hazards in the following sections.

A simplified diagram of an electric-power-distribution system is shown in figure 6.2. High Voltage (4800 V) enters the building-usually via underground cables. The secondary of a step down transformer develops 240 V. This secondary has a grounded center tap to provide two 120-V circuits between ground and each side of the secondary winding. Some heavy-duty devices such as air conditioners, electric dryers, and x-ray machines) require 240 V are placed across the entire secondary winding. Technicians do this by making connections to the two ungrounded metals.

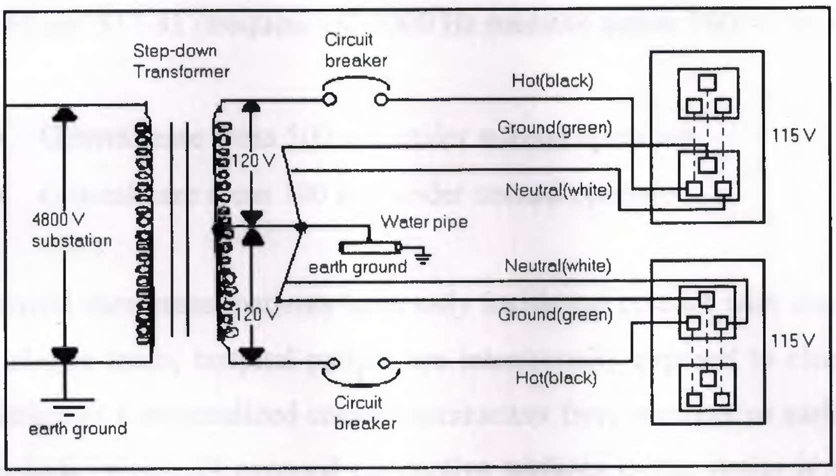


Figure 6.2 simplified electric power distribution 115v circuits.

Power frequency is 60Hz

Ordinary wall receptacles and lights operate on 120 V from either one of the ungrounded hot (Black) transform. Terminals and the neutral (white) grow4ed center tap. In addition for health-care facilities, the National

Electric Code (NEC) requires that all receptacles be grounded by a separate insole (green) copper conductor (Article 5 17-1 1). Some old installed used metal conductor as a ground conductor. This type of grow is generally unsatisfactory, because corrosion and loose connections are unreliable.

6.4 Patient's Electrical Environment

Of course, a shock hazard exists between the two cons supplying either a 240-V or a 120-V appliance. Since the nettle wire on a 120-V circuit is connected to ground, a connection between the hot conductor and any grounded object poses a shock hazard. Shocks can also occur if sufficient potentials exist between exposed conductive surfaces in the patients' environment. Minimum potentials permitted between any two exposed conductive surfaces in the vicinity of the patient are specified by the 197 NEC, Article 517-80 and 517-81 (frequency C 1000 Hz measure across 1000-fl resistance):

- General-care areas 500 mV under normal operation
- Critical-care areas 100 mV under normal operation

In general-care areas, patients have only incidental contact with electrical devices. For critical-care areas, hospital patient are intentionally exposed to electrical devices, and insulation of a externalized cardiac conductors from conductive surfaces is required. In critical-care areas, all exposed conductive surfaces in the victim it' of the patient must be grounded at a single patient-grounding point. Also, frequent periodic testing for continuity between the patient ground and all grounded surfaces is required.

Each patient-bed location in general-care areas must have at least four single or two duplex receptacles. Each receptacle must be grounded. At least two branch circuits with separate auto math over current devices must supply the location of each patient be for critical-care areas, at least six single or three duplex reacceptance are required for each location of a patient bed. Two branch circuit are also required, at least one being an individual branch circuit from a single panel board. An equipotent grounding system is also required for critical-care areas.

Emergency-power systems

Article 517 of the National Electrical Code (1978) specifies emergency electrical system required for health-care facilities. An emergency system is required that automatically restores power specified areas within 10 s after interruption of the normal source The emergency system may consist of two parts: (1) the life-safe branch (illumination, alarm, and alerting equipment), and (2) critical brand (lighting and receptacles in critical patient-care areas).

6.5 Macro Shock Hazards

The high resistance of dry skin and the spatial distribution current throughout the body when a person receives an electric shock are two factors that reduce the danger of ventricular fibrillation. Also electrical equipment is designed to minimize the possibility of humans coming into contact with dangerous voltages.

Skin and body resistance

The resistance of the skin limits the current that passes trough a person's body when the person comes into contact.

Electrical faults in equipment

All electrical devices are of course designed to minimize exposure of humans to hazardous voltages. However, many devices have a metal chassis and cabinet that can be touched by medical personnel and patients. If the chassis and cabinet are not grounded, then an insulation failure or shorted capacitor between the black hot power lead and the chassis results in a 115-V potential between the chassis and any grounded object if a person simultaneously touches the chassis and any grounded object, a macros hock results.

The chassis and cabinet can be grounded via a third green wire in the power cord and electrical system. This ground wire is connected to the neutral wire and ground at the power-distribution panel. Then, when a fault occurs between the hot conductor and the chassis, the current flows safely to ground on the green conductor. If the ground-wire resistance is very low, the voltage between the chassis and other grounded objects is negligible. If enough current flows through the ground wire to trip the circuit breaker, this will call people's attention to the fault.

Note that direct faults between the hot conductor or any high voltage in the device and ground are not common. Little or no current flows through the ground conductor during normal operation of electrical devices. The ground conductor is not needed for protection against macro shock until a hazardous fault develops. The broken ground wire or a poor connection of a receptacle ground is not detected during normal operation of the device. Consequently, continuity of the ground wire in the device and the receptacle must be periodically tested.

Faults inside electrical device may result from failures of hi-isolation, shorted capacitors, or mechanical Failures that cause short Power cords are particularly susceptible to strain and physical abuse, as are plugs and receptacles. Ironically, it is possible for a device's chassis and cabinet to become hot because a ground wire is in the power cord. If the ground wire is open anywhere between the power cord and ground, then a frayed cord could permit contact between the hot conductor and the broken ground wire leading to the chassis. Often, macro shock accidents result from carelessness and failure to correct known deficiencies in the power-distribution system and hi electrical devices.

Fluids such as blood, urine, IV solutions, and even baby formulas can conduct enough electricity to cause temporary short circuits if accidentally spilled into normally safe equipment. This hazard is particularly real in hospital areas that are subject to wet conditions, such as hem dialysis areas. Cabinets of many electrical devices have holes and vents for cooling that provide access for spilled conductive fluids. Designers of devices should protect patient electrical connections from this hazard.

6.6 Micro Shock Hazards

Micro shock accidents m electrically susceptible patient's ha½g direct electrical connections to the heart are usually caused by circumstances unrelated to macro shock hazards. Micro shocks usually result from leakage currents in line-operated equipment or differences in voltage between grounded conductive surfaces due to large currents in the grounding system. The micro shock current can flow either into or out of the electrical connection to the heart.

Leakage currents

Small currents (usually on the order of microamperes) that inevitably flow between any adjacent insulated conductors that are at different potentials we called leakage currents. Although most of the leakage current in line-operated equipment flows through the capacitance between the two conductors, some resistive leakage current flows through insulation, dust, and moisture.

The most important source of leakage currents is the currents that flow from all conductors in the electrical device to leads connected either to the chassis or to the patient. Leakage current flowing to the chassis flows safely to ground if a low-resistance ground wire is available, If the ground wire is broken, then the chassis potential will rise above ground, and a patient who touches the chassis and has a grounded electrical connection to the heart may receive a micro shock.

Conductive Surfaces

Between any two conductive surfaces near the patient can cause a micro shock if either surface makes contact to the heart and the other surface contacts any part of the body. Some examples are given later in this section

Conductive paths to the heart

Specific types of electrical connections to the heart can be identified. The following clinical makes make patients electrically susceptible to micro shock

1 Electrodes of externalized cardiac pacemakers

2 Electrodes for intracardiac ECG measuring devices

3 Liquid-filled catheters placed in the heart to:

A Measure blood pressure

B Withdraw blood samples

C Inject substances such as dye or drugs into the heart

It should be emphasized that an electrically susceptible patient is in danger of micro shock only if there is some electrical connection to the heart. The internal resistance of liquid-filled catheters is much greater (50 ohm-1 Mohm) than the resistance of metallic conductors in pacemaker and ECG electrode leads. Internal resistance of the body to micro shock is about 300, and the resistance of the skin can be quite variable, as discussed previously.

Roy (1976) showed that in dogs the surface area of the intracardiac electrode is an important determinant of minimum fibrillating current. As catheters get smaller, so do the total current needed to fibrillate. This means that current density at the tip of the intracardiac electrode is the important micro shock parameter. Smaller catheters tend to offer larger internal resistance.

Let us now discuss three examples of possible micro shock incidents, to illustrate how subtle micro shock hazards can be. These examples are illustrative only. They are certainly not the only ways that microshock can occur; they are not even necessarily the most probable.

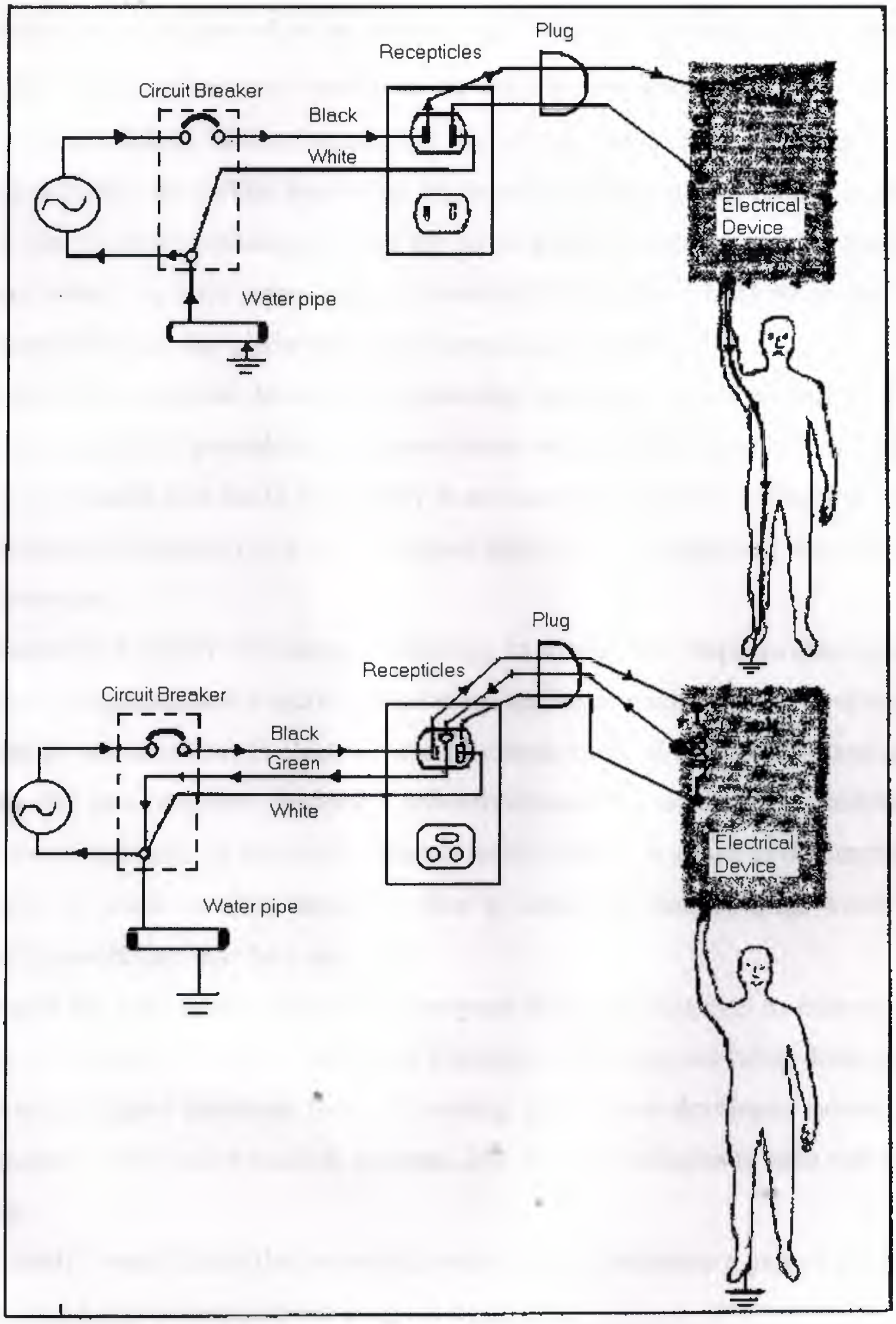


Figure 6.3 macroshock due to a ground fault from hot line to equipment
Grounded and ungrounded cases.

CONCLUSION

Human being is proved to be related with Electrical potential from many aspects. Electricity is fatal but at the same time we use it to save lives.

Electrical medical device technology is saving and improving quality of life by detecting diseases earlier, improving diagnosis and hence giving prompt cure like ECG that detects heart pathology before the more massive damage and the patient can be saved from long term complications. Similarly CT scan and MRI also have a vital role in early detection and observation of progress and treatment.

Further more medical devices are enhancing the skill of medical staff by performing more complicated procedures with much more accuracy then ever before. They are also reducing health care costs. Ergometer is an example of an easy affordable device used to measure the stamina of a sportsman and shows if he is improving or not in his routine of exercise.

Robotics is a rapidly developing technology in surgery that requires close collaboration between engineers and surgeons, since machines act as remote extensors of surgeons.

With the advancement in electrical and electronic medical devices, telemedicine is now possible that exploits two-way telecommunication technology, multimedia and computer networks to deliver or enhance health care. It is aimed at the improvement of quality of health care for those who live in remote or isolated areas where excess to quality health care may be a problem.

Despite the considerable efforts and progress there are obstacles to achieve the global implementation of these technologies. Currently researches are being done to overcome the technological problems faced. In coming years, more developed systems are to be expected to offer more modern, accurate, low cost technologies to save valuable human lives.

Certainly I won't claim that my words with their hue delineate a perfect picture but it is a try that helps to peep into the world of biomedics.

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