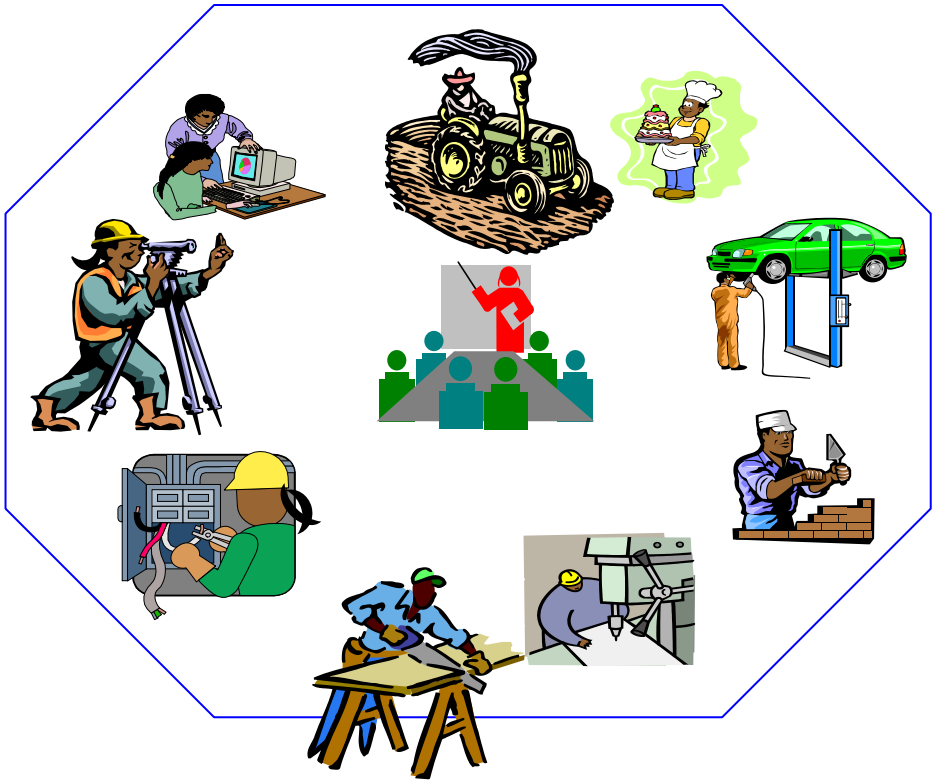
Intermediate Biomedical Equipment Servicing Level-III

Based on May, 2011 Version 2 OS and February, 2021 Version 1

Curriculum



Module Title: Maintaining and Repairing Biomedical Equipment Control Systems

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L #23	LO 1-Plan and prepare for maintenance/ repair

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Planing and preparing maintenance work.
- Following OHS policies and procedures.
- Identifying biomedical equipment control systems (BMECS).
- Identifying BMECS to be maintained.
- Checking BMECS for maintenance.
- Obtaining necessary materials.
- Obtaining tools, equipment and testing devices.

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Plan and prepare maintenance work.
- Follow OHS policies and procedures.
- Identify biomedical equipment control systems (BMECS).
- Identify BMECS to be maintained.
- Check BMECS for maintenance.
- Obtain necessary materials.
- Obtain tools, equipment and testing devices.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them.
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet 1- Planing and preparing maintenance work

1.Planing and preparing maintenance work

Maintenance is a set of organised activities that are carried out in order to keep an item in its best operational condition with minimum cost acquired. The combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.

Maintenance Activities

Activities of maintenance function could be either repair or replacement activities, which are necessary for an item to reach its acceptable productivity condition or these activities, should be carried out with a minimum possible cost.

1.1 Types of Medical Equipment Maintenance

Medical equipment brings along with it associated benefits and problems. The problem that draws the most attention is maintenance. Lack of a maintenance policy can result in no advance planning for maintenance budgets and thus no availability of spares and accessories. Many laboratories and health care programs suffer because the installation

and maintenance requirements are not planned in advance. This renders much equipment unusable and many devices lie idle because of lack of spares or funds.

Effective Maintenance Strategy

It is essential that we plan the resources required for maintenance. Planning will need to be made for both repair work and also for planned preventive maintenance. The following will also promote effective maintenance:

User as well as service manuals

- In procurement it should be made mandatory for the vendors to provide the following:
  - ✓ Training to technicians and operators.
  - ✓ Providing user / operating manuals.
  - ✓ Providing service / maintenance manuals

1. **Receipt and incoming inspection**
   - Incoming equipment should be carefully checked for possible shipment damages; compliance with specifications in the purchase order; and delivery of accessories, spare parts and operating and service manuals.
2. **Inventory and documentation**
   - A proper entry should be made in the inventory register. The inventory record should contain the serial number and date of receipt as well as date of completed inspection.
3. **Installation and final acceptance**
   - Installation should be done by the vendor and training should be provided at this stage to the user as well as to the maintenance technicians.
4. **Equipment history record**
   - There should be an equipment history record sheet to track the performance of the equipment. This sheet should note down the date of installation and commissioning, preventive as well as corrective maintenance records.
5. **Maintenance**

- Proper maintenance of medical equipment is essential to obtain sustained benefits and to preserve capital investment. Medical equipment must be maintained in working order and periodically calibrated for effectiveness and accuracy.

6. Condemnation of old and obsolete equipment

- The life cycle of medical equipment will vary from 5-10 years. If the equipment is declared obsolete by the vendor it may not be possible to get spare parts. Even if the parts are available it can become too expensive to obtain them and the equipment is no longer economical to repair. Condemnation of equipment should be well planned and the necessary steps should be taken in advance to arrange replacement

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 1point)

1._____ is a set of organized activities that are carried out in order to keep an item in its best operational condition with minimum cost acquired..

A. Procedure B. inspection C. Maintenance D) None

2. which of following is correct to promote effective maintenance strategy

A. Receipt and incoming inspection C.Installation and final acceptance

B. Investigate refusals to work D) User as well as service manuals

Answer Sheet

Name: _____ Date: _____

Score = _____
Rating: _____

Information Sheet 2- Follow OHS policies and procedures

2. Follow OHS policies and procedures

2.1. Hazard and risk assessment

Hazards exist in every workplace in many different forms: sharp edges, falling objects, flying sparks, chemicals, noise and a myriad of other potentially dangerous situations. The Occupational Safety and Health Administration (OSHA) requires that employers protect their employees from workplace hazards that can cause injury.

Controlling a hazard at its source is the best way to protect employees. Depending on the hazard or workplace conditions, OSHA recommends the use of engineering or work practice controls to manage or eliminate hazards to the greatest extent possible. For example, building a barrier between the hazard and the employees is an engineering control; changing the way in which employees perform their work is a work practice control.

When engineering, work practice and administrative controls are not feasible or do not provide sufficient protection, employers must provide personal protective equipment (PPE) to their employees and ensure its use. Personal protective equipment, commonly referred to as “PPE”, is equipment worn to minimize exposure to a variety of hazards. Examples of PPE include such items as gloves, foot and eye protection, protective hearing devices (earplugs, muffs) hard hats, respirators and full body suits.

This guide will help both employers and employees do the following:

- Understand the types of PPE.
- Know the basics of conducting a “hazard assessment” of the workplace.
- Select appropriate PPE for a variety of circumstances.
- Understand what kind of training is needed in the proper use and care of PPE.

Occupational Health and Safety and You

One of your most important responsibilities is to protect your Health and Safety as well as that of your co-workers. This will discuss some of your duties under the occupational Health and Safety legislation and help you to make your workplace safer and healthier.

You have responsibilities to:

- You must also comply with the legislation.
- Protect your own Health and Safety and that of your co-workers;
- Not initiate or participate in the harassment of another worker; and
- Co-operate with your supervisor and anyone else with duties under the legislation.

Your Rights

- The right to know the hazards at work and how to control them;
- The right to participate in Occupational Health and Safety; and
- The right to refuse work which you believe to be unusually dangerous.
- You may not be punished for using these rights.
- An employer can be required to legally justify any action taken against a worker who is active in Health and Safety.

Your Right to Know and Participate

If you are inexperienced, you must receive an orientation which includes;

- Plan and prepare maintenance work.
- What to do in a fire or other emergency;
- First aid facilities;
- Prohibited or restricted areas;
- Workplace hazards; and
- Any other information you should know.
- You must also be supervised closely by a competent supervisor.
- Regularly inspect the workplace;
- Conduct accident investigations;
- Deal with the Health and Safety concerns of employees;
- Investigate refusals to work. And

- Continue refusal measures have been taken to satisfy you that the job is now safe to perform

The Requirement for PPE

To ensure the greatest possible protection for employees in the workplace, the cooperative efforts of both employers and employees will help in establishing and maintaining a safe and healthful work environment.

In general, you should:

- Properly wear PPE,
- Attend training sessions on PPE,
- Care for, clean and maintain PPE, and
- Inform a supervisor of the need to repair or replace PPE.

Specific requirements for PPE are presented in many different OSHA standards.

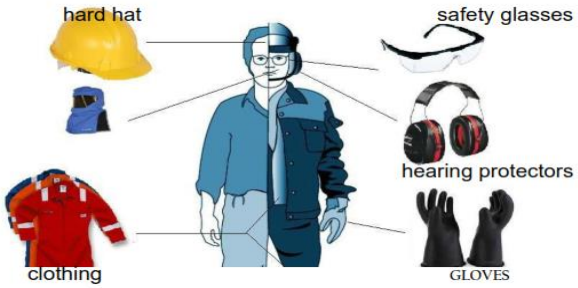

Figure 2.1: PPE

The Hazard Assessment

A first critical step in developing a comprehensive safety and health program is to identify physical and health hazards in the workplace. This process is known as a "hazard assessment." Potential hazards may be physical or health-related and a comprehensive hazard assessment should identify hazards in both categories.

Examples of physical hazards include moving objects, fluctuating temperatures, high intensity lighting, rolling or pinching objects, electrical connections and sharp edges. Examples of health hazards include overexposure to harmful dusts, chemicals or radiation.

The hazard assessment should begin with a walkthrough survey of the facility to develop a list of potential hazards in the following basic hazard categories:

- Impact
- Penetration
- Compression (roll-over),
- Chemical,
- Heat/cold,
- Harmful dust,
- Light (optical) radiation, and
- Biologic.

In addition to noting the basic layout of the facility and reviewing any history of occupational illnesses or injuries, things to look for during the walkthrough survey are

- Sources of electricity.
- Sources of motion such as machines or processes where movement may exist that could result in an impact between personnel and equipment.
- Sources of high temperatures that could result in burns, eye injuries or fire.
- Types of chemicals used in the workplace.
- Sources of harmful dusts.
- Sources of light radiation, such as welding, brazing, cutting, furnaces, heat treating, high intensity lights, etc.
- The potential for falling or dropping objects.
- Sharp objects that could poke, cut, stab or puncture.
- Biologic hazards such as blood or other potentially infected material.

When the walkthrough is complete, the employer should organize and analyze the data so that it may be efficiently used in determining the proper types of PPE required at the worksite. It is definitely a good idea to select PPE that will provide a level of protection greater than the minimum required to protect employees from hazards.

The workplace should be periodically reassessed for any changes in conditions, equipment or operating procedures that could affect occupational hazards. This periodic reassessment should also include a review of injury and illness records to spot any trends or areas of concern and taking appropriate corrective action. The suitability of existing PPE, including an evaluation of its condition and age, should be included in the reassessment.

Documentation of the hazard assessment is required through a written certification that includes the following information:

- Identification of the workplace evaluated;
- Name of the person conducting the assessment;
- Date of the assessment; and
- Identification of the document certifying completion of the hazard assessment.

Electrical Safety Hazards

When electrical systems break down what are the primary hazards and what are the consequences to personnel are

- Electric shock-
- Exposure to Arc-Flash
- Exposure to Arc-Blast
- Exposure to excessive light and sound energies

Secondary hazards may include burns, the release of toxic gases, molten metal, airborne debris and shrapnel. Unexpected events can cause startled workers to lose their balance and fall from ladders or jerk their muscles possibly causing whiplash or other injuries.

2.2. Implementation of safety regulations

In the performance of your duties, you come across many potentially dangerous conditions and situations. You install, maintain, and repair electrical and electronic equipment in confined spaces where high voltages are present. Among the hazards of this work are injury caused by electric shock, electrical fires, and harmful gases. Also,

you must include improper use of tools among these hazards. Common sense and carefully following established rules will produce an accident-free naval career.

Whenever you're working on any electronic equipment, your own safety has to come first. Every electronic technician must always take safety precautions before he or she starts work.

Electricity must be handled properly, or else it can injure or cause fatalities. Here are some basic steps that show you how to avoid accidents from occurring.

- **Electrical Shock**

Once you open up a set cover, you're actually exposing yourself to the threat of electric shock. Always keep in mind that safety has to come first. A serious shock may stop your heart and if large electric current flows through your body, you will receive serious burns.

There are three basic pathways electric current travels through the body;

1. Touch Potential (hand/hand path)

The current travels from one hand through the heart and out through the other hand. Because the heart and lungs are in the path of current, ventricular fibrillation, difficulty in breathing, unconsciousness, or death may occur.

2. Step Potential (foot/foot path)

The current travels from one foot through the legs, and out of the other foot. The heart is not in the direct path of current but the leg muscles may contract, causing the victim to collapse or be momentarily paralyzed.

3. Touch/Step Potential (hand/foot path)

The current travels from one hand, through the heart, down the leg, and out of the foot. The hear t and lungs are in the direct path of current so ventricular fibrillation.

Even though there may be no external signs from the electrical shock, internal tissue or organ damage may have occurred. Signs of internal damage may not surface immediately; and when it does, it may be too late. Any person experiencing any kind of electrical shock should seek immediate medical attention. Using the correct personal protective equipment (PPE) and following safe work practices will minimize risk of electrical shock hazards.

Figure 2..2: Illustrates the path of current through the body.

Here are some rules, which should help you to avoid electricity hazards.

- Always turn off the equipment and unplug it before you begin to work.
- If you have to run tests while the equipment is operating, turn the equipment on, make your test carefully, and then turn the equipment off again.
- Wear rubber bottom shoes or sneakers.
- Try to do the work with one hand, while keeping the other in your pocket. That keeps the possible current paths away from the heart.
- Don't attempt repair work when you are tired or rushed.
- Always assume that all the parts in the power supply are "HOT".
- Use only plastic screwdriver for shock protection during service

2.3. Basic electrical safety rule concepts

Electrical Safety in the workplace can only be attained when trainees (workers) and companies diligently follow OSHA and industry accepted standards and regulations. It is our sincere hope and desire that this handbook has been helpful in informing the reader

of the importance of Electrical Safety while providing methods and information on how to effectively and safely reduce electrical hazards are

- Unless there is a compelling safety issue such as life-support equipment, alarm systems, hazardous location ventilation, or lighting required for safety, OSHA requires that circuits be de-energized and the system be placed in an Electrically Safe Work Condition before any work is performed.
- When placing equipment in an Electrically Safe Work Condition always follow proper Lockout/tagout procedures.
- An Electrical Hazard Analysis must be performed on all circuits 50 volts and higher that may be worked on while energized.
- The Hazards must be identified and warning labels must be applied to all equipment that may be worked on while energized.
- Trainees must be trained on the equipment, hazards and safety precautions, and be certified as “qualified” to work on energized equipment. Training and certification must be documented.
- All work performed on energized equipment must be preceded by a job briefing and a signed Energized Electrical Work Permit.
- When working on or approaching energized circuits, proper protective clothing must be worn. The minimum flame retardant clothing, safety glasses, and protective gloves and equipment must meet OSHA and NFPA 70E guidelines. Protective insulating blankets and mats are also used to minimize exposure.
- Be certain there is adequate lighting for the tasks to be performed. Portable lighting must be fully insulated so that it will not accidentally cause short circuits when used near energized components.
- Use barricades or barriers to warn unqualified individuals from entering the area.
- Be prepared for the unexpected. Make sure emergency communications and trained medical personnel are available if something goes wrong.
- Use current-limiting over current protective devices wherever possible to reduce the potential electrical hazards.

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. what is your responsibilities to occupational Health and Safety legislation (4%)
   A. Protect your own Health and Safety and that of your co-workers
   B. Conduct accident investigations
   C. Deal with the Health and Safety concerns of employees;
   D. Investigate refusals to work
2. When electrical systems break down what are the primary hazards and what are the consequences to personnel? (4%)

   A. Electric shock C. Exposure to Arc-Flash
   B. Exposure to Arc-Blast D. All
3. The basic pathways electric current travels through the body (4%)
   A. Touch Potential (hand/hand path)
   B.Step Potential (foot/foot path)
   C.Touch/Step Potential (hand/foot path)
   D. All

. Answer the following question!

Note: **Satisfactory rating -10 and 12 points Unsatisfactory - below 7and 12 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Name: _____ Date: _____

Short Answer Question

Score = _____
Rating: _____

Information Sheet 3. Identifying biomedical equipment control systems (BMECS)

3. Identifying biomedical equipment control systems (BMECS)

3.1. Control systems

System – An interconnection of elements and devices for a desired purpose.

Control System – An interconnection of components forming a system configuration that will provide a desired response.

Process – The device, plant, or system under control. The input and output relationship represents the cause-and-effect relationship of the process.

Figure 3.1 Control System

Control System

A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input. Figure shows a control system in its simplest form, where the input represents a desired output.

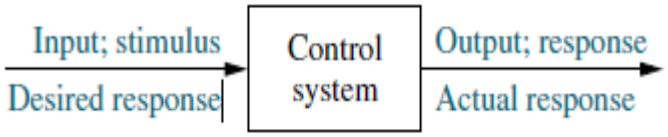

Figure 3.2 Control subsystems and processes

3.1.1 Control System Terminology

To discuss control systems, we must first define several key terms.

- ***Input-***Stimulus or excitation applied to a control system from an external source, usually in order to produce a specified response from the system.
- ***Output-*** The actual response obtained from the system. It may or may not be equal to the specified response implied by the input.
- ***Feedback-*** That portion of the output of a system that is returned to modify the input and thus serve as a performance monitor for the system.
- ***Error-*** The difference between the input stimulus and the output response. Specifically, it is the difference between the input and the feedback.

Controlled Variable– It is the quantity or condition that is measured and Controlled. Normally *controlled variable* is the output of the control system.

Manipulated Variable– It is the quantity of the condition that is varied by the controller so as to affect the value of *controlled variable*.

Control – Control means measuring the value of *controlled variable* of the system and applying the *manipulated variable* to the system to correct or limit the deviation of the measured value from a desired value.

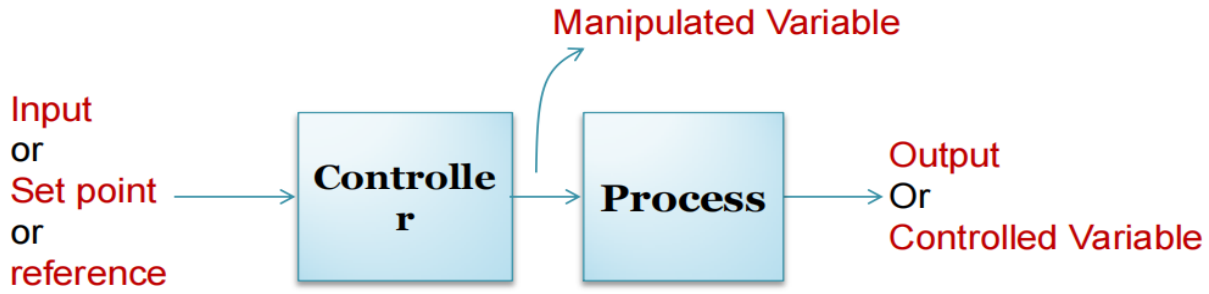

Figure 3.3 C*ontrolled variable* of the system and applying the *manipulated variable*

Disturbances– A disturbance is a signal that tends to adversely affect the value of the system. It is an unwanted input of the system.

- If a disturbance is generated within the system, it is called *internal disturbance*. While an *external disturbance* is generated outside the system.

Example 1

- A very simple example of a feedback control system is the **thermostat**. The *input* is the temperature that is initially set into the device.
- Comparison is then made between the input and the temperature of the outside world.
- If the two are different, an *error* results and an *output* is produced that activates a heating or cooling device.
- The comparator within the thermostat continually samples the ambient temperature, i.e., the *feedback,* until the *error* is zero; the *output* then turns off the heating or cooling device.

Example 2

- The seemingly simple act of *pointing at an object with a finger requires a biological control system* consisting chiefly of the eyes, the arm, hand and finger, and the brain. The input is the precise direction of the object (moving or not) with

respect to some reference, and the output is the actual pointed direction with respect to the same reference.

- A part of the human temperature control system is the *perspiration system. When the temperature* of the air exterior to the skin becomes too high the sweat glands secrete heavily, inducing cooling of the skin by evaporation. Secretions are reduced when the desired cooling effect is achieved, or when the air temperature falls sufficiently. The input to this system may be “normal” or comfortable skin temperature, a “setpoint,” or the air temperature, a physical variable. The output is the actual skin temperature.

Advantages of Control Systems

We build control systems for four primary reasons:

1. Power amplification
2. Remote control
3. Convenience of input form
4. Compensation for disturbances

Examples of Control Systems

- A Model of Heart Rate Control System

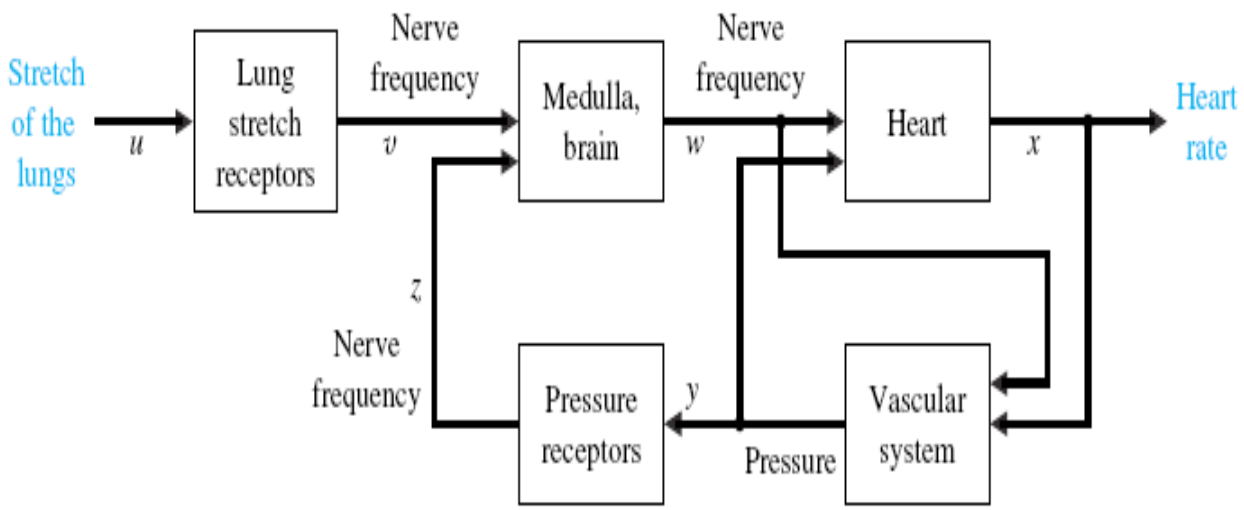

Figure 3.4 A Model of Heart Rate Control System

Examples of Modern Control Systems

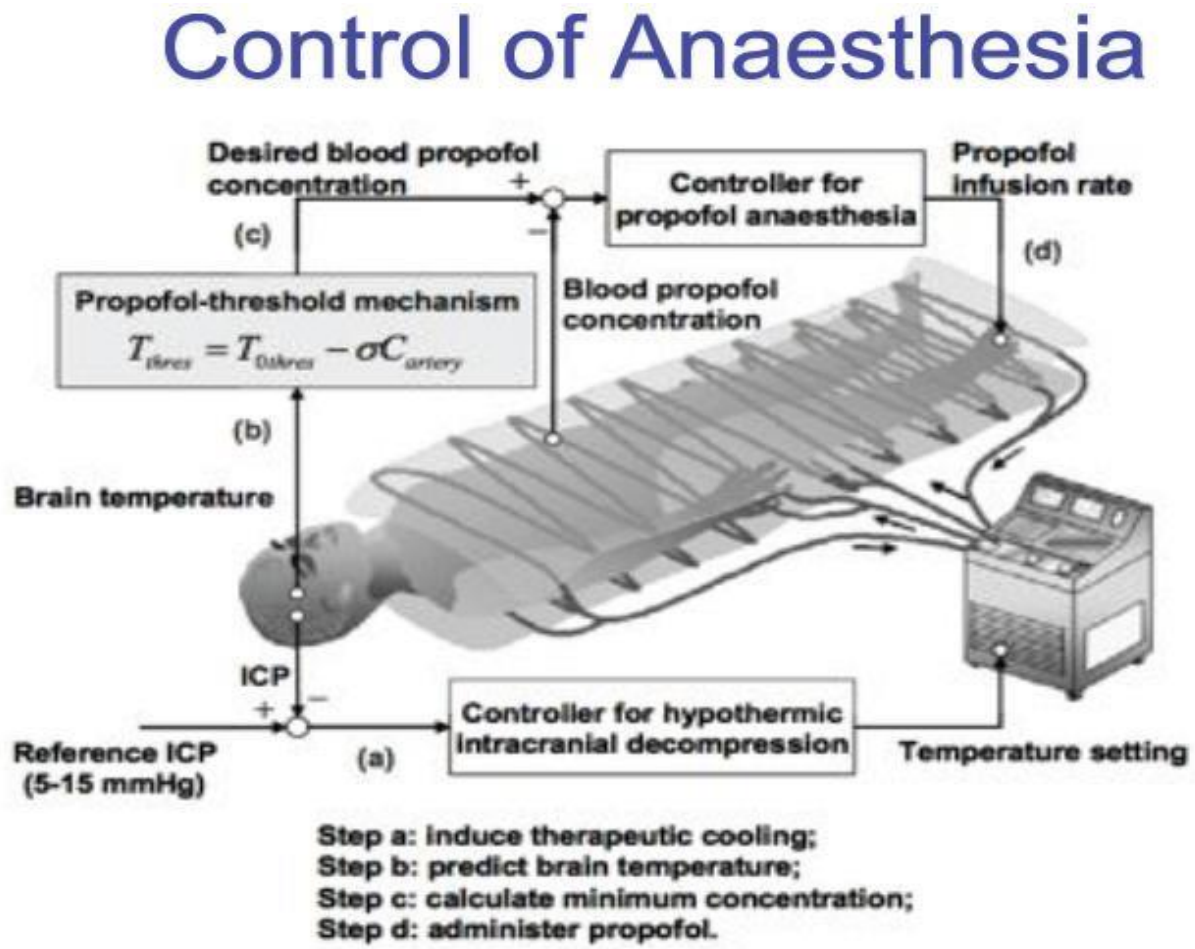

Figure 3.4 A Model of Heart Rate Control of Anaesthesia

3.2. Introduction to Biomedical Instruments

"Biomedical instruments" refer to a very broad class of devices and systems. A biomedical instrument is an ECG machine to many people. To others, it's a chemical biosensor, and to some it's a medical imaging system. Current estimates place the worldwide market for biomedical instruments at over $200 billion. Biomedical instruments are ubiquitous; they are significant to the broader technology and biotechnology sectors; and, finally, they are vital to many medical and scientific fields. Bottom line:

Even though there is a wide variety of an instrument, almost all of them can be modeled using the simple diagram below.

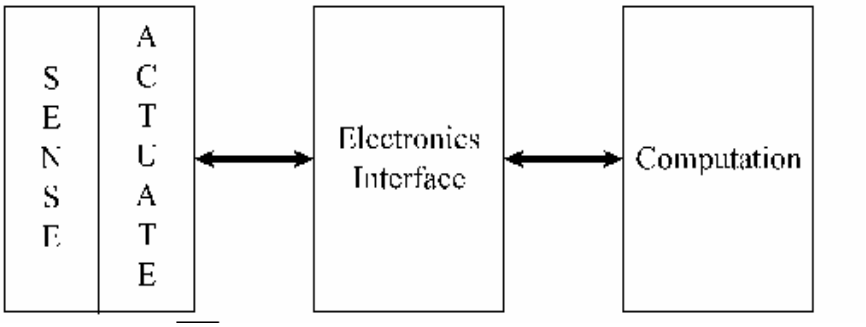

Figure 3.5: *Basic model of instrumentation systems.*

All biomedical instruments must interface with biological materials (by definition). The interface can by direct contact or by indirect contact (e.g., induced fields).

In this course we will primarily study sensing systems, which means that the system front-end will generally be a sensing element. Other than this restriction, we will cover all aspects of typical biomedical instrumentation systems.

We will do them in the following order:

1. **Basic Sensors and Principles** -- including bio potential electrodes

2. **Electronic Interfacing**: including system noise figure, system bandwidth, pre-amplifiers, post amps, instrumentation amps, A/D and D/A converters, aliasing, triggering and signal averaging
3. **Computation**: including data capture and signal processing
4. **Systems**: complete system response using specific examples (electromyogram, pressure sensors and blood pressure measurements, flow sensors and blood flow measurements, and chemical biosensors)

3.2.1. Sensors and Actuators

A sensor must:

- detect biochemical, bioelectrical, or biophysical parameters
- reproduce the physiologic time response of these parameters
- provide a safe interface with biological materials

An actuator must:

- deliver external agents via direct or indirect contact
- control biochemical, bioelectrical, or biophysical parameters
- provide a safe interface with biologic materials

3..2.2. Electronics Interface

The electronics interface must:

- match the electrical characteristics of the sensor/actuator with the computation unit
- preserve signal-to-noise ratio (SNR) of sensor
- preserve efficiency of actuator
- preserve bandwidth (i.e., time response) of sensor/actuator
- provide a safe interface with the sensor/actuator
- provide a safe interface with the computation unit
- provide secondary signal processing functions for the system

3.2.3 Computation Unit

The computation unit must:

- provide primary user interface

- provide primary control for the overall system
- provide data storage for the system
- provide primary signal processing functions for the system
- maintain safe operation of the overall system

3.2.4 Types of Biomedical Instrumentation Systems

Types of Biomedical Instrumentation Systems

- Direct / Indirect
- Invasive / Noninvasive
- Contact / Remote
- Sense / Actuate
- Dynamic / Static

Direct/Indirect: The sensing system measure a physiologic parameter directly, such as the average volume blood flow in an artery, or measures a parameter **related to** the physiologic parameter of interest (e.g., ECG recording at the body surface is related to propagation of the action potential in the heart but is **not a** measurement of the propagation waveform).

Invasive/Noninvasive: Direct electrical recording of the action potential in nerve fibers using an implantable electrode system is an example of an invasive sensor. An imaging system measuring blood flow dynamics in an artery (e.g., ultrasound color flow imaging of the carotid artery) is an example of a non-invasive sensor.

Contact/Remote: A strain gauge sensor attached to a muscle fiber can record deformations and forces in the muscle. An MRI or ultrasound imaging system can measure internal deformations and forces without contacting the tissue.

Sense/Actuate: A sensor detects biochemical, bioelectrical, or biophysical parameters. An actuator delivers external agents via direct or indirect contact and/or controls biochemical, bioelectrical, or biophysical parameters. An automated insulin delivery pump is an example of a direct, contact actuator.

Noninvasive surgery with high intensity, focused ultrasound (HIFU) is an example of a remote, noninvasive actuator.

Dynamic/Static: Static instruments measure temporal averages of physiologic parameters. Real-time instruments have a time response faster than or equal to the physiologic time constants of the sensed parameter. For example a real-time, ultrasound Doppler system can measure changes in arterial blood velocity over a cardiac cycle.

3.2.5 Medical Measurement Parameters

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3.2.6 Characteristics of Signals

"A signal is any physical quantity that varies with time (or other independent variable) and carries information. Signals can be classified as either continuous or discrete. A continuous signal changes smoothly, without interruption. A discrete signal changes in definite steps, or in a quantized manner.

The terms *continuous* and *discrete* can be applied either to the value (amplitude) or to the time characteristics of a signal"

In nature (including biology), most signals are *analog*, i.e., they take on continuous values (amplitude and time) within a particular range.

"*Continuous-time*":signals exist continually at all times (during a specified time period).

"*Discrete-time*": signals are defined only at selected instances of time.

Sampling: is the process to convert continuous-time signals to discrete-time signals.

Quantizing: is the process that converts continuous (in amplitude) discrete-time signals to digital signals.

Signals in which time is the independent variable are referred to as "*time-domain*" signals. Likewise, when frequency is the independent variable, the signals are referred to as "*frequency-domain*" signals.

3.3. General Instrument Performance Parameters

3.1.1 Systematic and Random Error

Systematic errors are errors that consistently occur in a measurement in the same direction. The common sources of systematic errors are inaccurate calibration, mismatched impedances, response-time error, nonlinearities, equipment malfunction, environmental change, and loading effects. Systematic errors are often unknown to the user. The best way to detect systematic errors are to repeat the measurement with a completely different technique using different instruments.

Random errors tend to vary in both directions from the true value randomly (or stochasticly). With properly designed instruments, random errors are generally small relative to the *measurand* (the physical signal to be measured). Common sources of random error include electrical noise, interference, vibration,

gain variation of amplifiers, leakage currents, drift, observational error, motion artifact (for contact sensors), random interfering inputs, etc.

3.1.2 Static Performance Parameters

Static characteristics describe the performance for dc or very low frequency inputs. The properties of the output for a wide range of constant inputs demonstrate the quality of the measurement.

Accuracy

The accuracy of a single measured quantity is the difference between the true value and the measured value divided by the true value:

$$Accuracy = \frac{True\ value - measured\ value}{True\ value}$$

Accuracy is often quoted as a percentage. Many times, the true value is unknown overall operating conditions, so the true value is approximated with some standard.

Precision

The precision of a measurement expresses the number of distinguishable alternatives from which a given result is selected. On most modern instrumentation systems the

precision is ultimately determined by the analog-to-digital converter *(AID)* characteristics.

Resolution

The smallest quantity that can be measured with certainty is the resolution. Resolution expresses the degree to which nearly equal values of a quantity can be discriminated.

Reproducibility

The ability of an instrument to give the same output for equal inputs applied over some period of time is called reproducibility. Drift is the primary limit on reproducibility.

Sensitivity

Sensitivity describes changes in system output for a given change in a single input. It is quantified by holding all inputs constant except one. This one input is varied incrementally over the normal operating range, producing a range of outputs needed to compute the sensitivity.

Zero (Offset) Drift

Offset drift is one parameter determining reproducibility. It is measured by monitoring the system output with no change in input. Any changes that occur are simply result of system offset.

Sensitivity Drift

Sensitivity drift is the second primary contributor to irreproducibility. It causes error proportional to the magnitude of the input. These drift parameters are summarized in a typical sensor sensitivity curve below.

This is the simple expression of the superposition principle for a linear system. There are many ways to express deviations from linearity for a practical system. For dynamic systems, multitone tests are often used, where the magnitude of beat frequencies between the individual tone frequencies can quantify the level of nonlinearity. For static systems, independent nonlinearity measures as shown below are often used

Dynamic Range

The dynamic range defines the ratio between the maximum undistorted signal (i.e., maximum input signal satisfying the linearity specification for the sensor) and the

minimum detectable signal for a given set of operating conditions. Often the dynamic range is quoted on a logarithmic scale (i.e., dB scale).

Input Impedance

The instantaneous rate at which energy is transferred by a system (i.e., the power) is proportional to the product of an *effort* variable (e.g., voltage, pressure, force) with a *flow* variable (current, flow, velocity).

The generalized impedance, ***Z***, is the ratio of the phasor equivalent of the steady-state sinusoidal effort variable to the phasor equivalent of the steady-state flow variable:

$$\tilde{Z} = \frac{\tilde{V}}{\tilde{I}}$$

where the tilde denotes phasor variables (i.e., magnitude and phase—a complex number). The phase is related to the response lag of the system to a sinusoidal input - more about this for dynamic systems.

Self-Check -3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Chose the correct answer

1. _____**:** The sensing system measure a physiologic parameter directly, such as the average volume blood flow in an artery,
   A. Direct/Indirect B. Invasive C. Contact / Remote D. Dynamic / Static
2. _____**:** Direct electrical recording of the action potential in nerve fibers using an implantable electrode system is an example of an invasive sensor.
   A. Direct/Indirect B. Invasive C. Invasive/Noninvasive D. Dynamic / Static
3. _____**:** A strain gauge sensor attached to a muscle fiber can record deformations and forces in the muscle.
   A. Direct/Indirect B. Invasive C. Invasive/Noninvasive D. Contact/Remote
4. A sensor must NOT:
   A. detect biochemical, bioelectrical, or biophysical parameters
   B. reproduce the physiologic time response of these parameters
   C. provide a safe interface with biological materials D. None
5. **An actuator must:**
   A. deliver external agents via direct or indirect contact
   B. control biochemical, bioelectrical, or biophysical parameters
   C. provide a safe interface with biologic materials D. All
6. The electronics interface must not:
   A. preserve signal-to-noise ratio (SNR) of sensor C. preserve efficiency of actuator
   B. Invasive/Noninvasive D. preserve bandwidth
7. The computation unit must:
   A. provide primary user interface C. Invasive/Noninvasive
   B. provide data storage for the system D. A and B
8. which one the following is not the types of biomedical Instrumentation Systems
   B. Direct / Indirect C. Invasive / Noninvasive
   C. Contact / Remote D.None

Note: **Satisfactory rating - 4 and 8 point Unsatisfactory - below 4 and 8 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Information Sheet 4. Identifying BMECS to be maintained

4. Identifying BMECS to be maintained

4.1. Sensors and signal processing

4.1.1. Displacement and position sensors

Displacement sensors are basically used for the measurement of movement of an object. Position sensors are employed to determine the position of an object in relation to some reference point.

Proximity sensors are a type of position sensor and are used to trace when an object has moved with in particular critical distance of a transducer.

Displacement sensors

1. Potentiometer Sensors

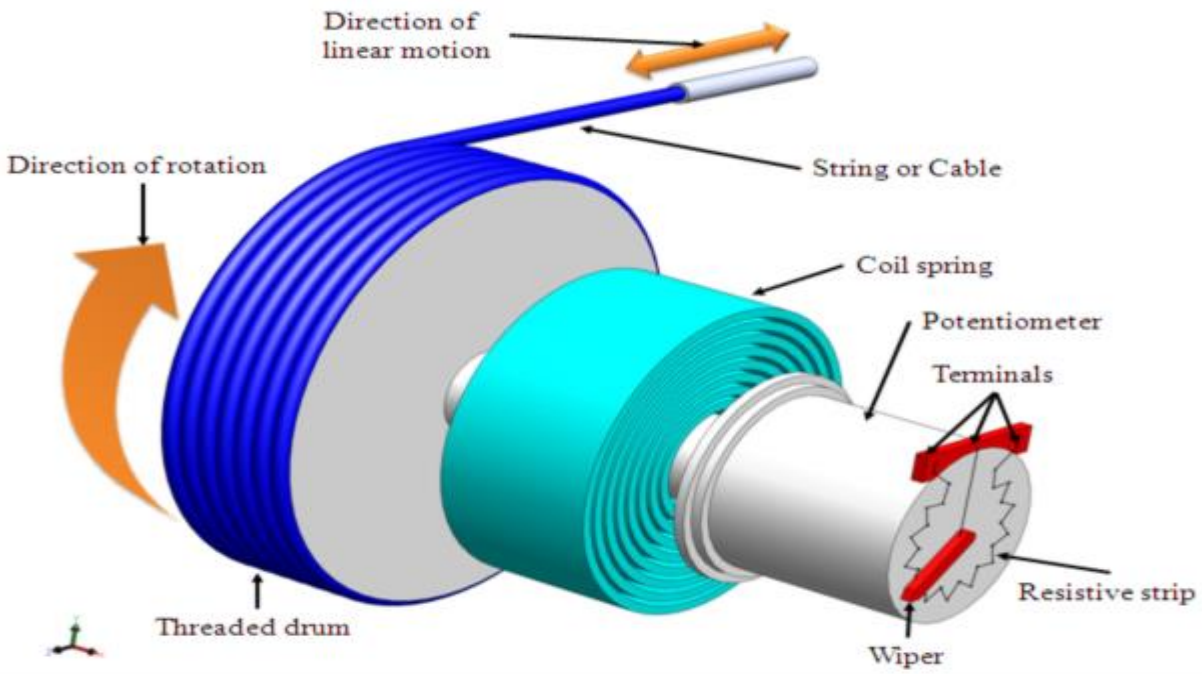


Figure 4.1 Potentiometer Sensors

Figure shows the construction of a rotary type potentiometer sensor employed to measure the linear displacement. The potentiometer can be of linear or angular type. It works on the principle of conversion of mechanical displacement into an electrical

signal. The sensor has a resistive element and a sliding contact (wiper). The slider moves along this conductive body, acting as a movable electric contact.

The object of whose displacement is to be measured is connected to the slider by using

- a rotating shaft (for angular displacement)
- a moving rod (for linear displacement)
- a cable that is kept stretched during operation

2. *Strain Gauges*

The strain in an element is a ratio of change in length in the direction of applied load to the original length of an element. The strain changes the resistance *R* of the element. Therefore, we can say,

$\Delta R/R \alpha \varepsilon$;

$\Delta R/R = G \varepsilon$

where G is the constant of proportionality and is called as gauge factor. In general, the value of G is considered in between 2 to 4 and the resistances are taken of the order of 100 Ω.

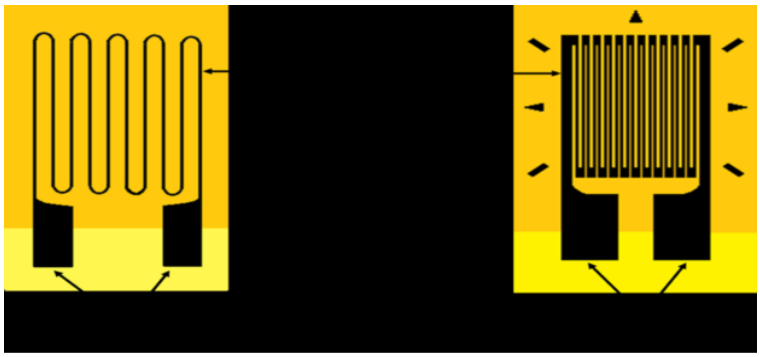


Figure 4.2 Strain Gauges

3. *Capacitive element based sensor*

Capacitive sensor is of non-contact type sensor and is primarily used to measure the linear displacements from few millimeters to hundreds of millimeters. It comprises of three plates, with the upper pair forming one capacitor and the lower pair another. The linear displacement might take in two forms:

a. One of the plates is moved by the displacement so that the plate separation changes
b. Area of overlap changes due to the displacement.

Figure shows the schematic of three-plate capacitive element sensor and displacement measurement of a mechanical element connected to the plate 2

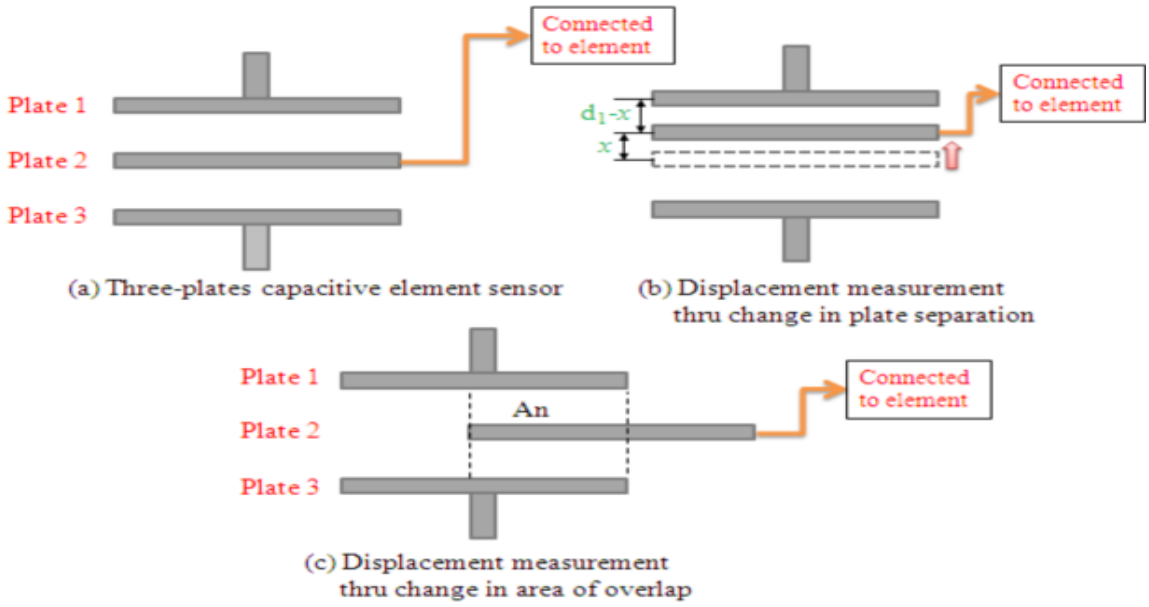


Figure 4.3 Three-plate capacitive element sensor

1. *Linear variable differential transformer (LVDT)*

Linear variable differential transformer (LVDT) is a primary transducer used for measurement of linear displacement with an input range of about ± 2 to ± 400 mm in general. It has non-linearity error ± 0.25% of full range. Figure shows the construction of a LVDT sensor

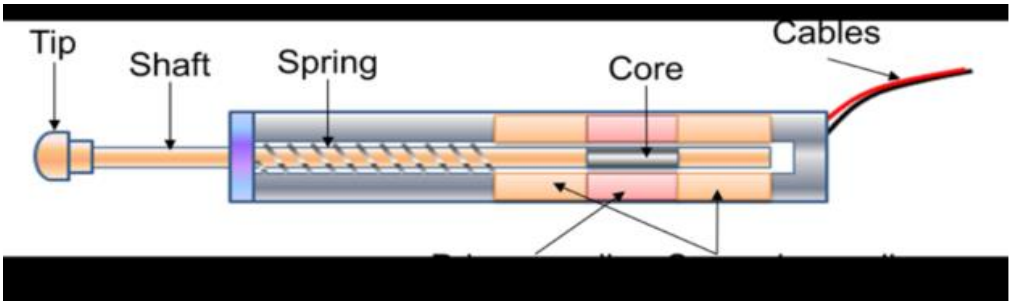


Figure 4.4 Linear variable differential transformer (LVDT)

It has three coils symmetrically spaced along an insulated tube. The central coil is primary coil and the other two are secondary coils. Secondary coils are connected in series in such a way that their outputs oppose each other. A magnetic

core attached to the element of which displacement is to be monitored is placed inside the insulated tube.

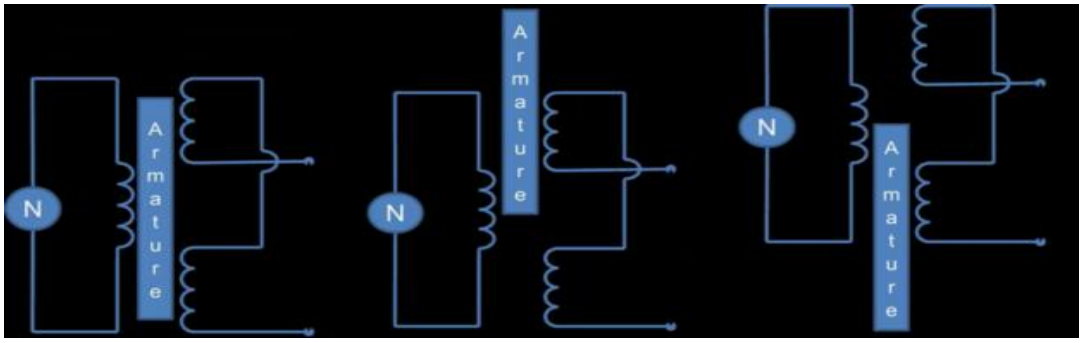


Figure 4.5 shows the construction of a LVDT sensor

4.2. Sensors and signal processing

Displacement, position and proximity sensors

1. Eddy current proximity sensors

Eddy current proximity sensors are used to detect non-magnetic but conductive materials. They comprise of a coil, an oscillator, a detector and a triggering circuit. Figure shows the construction of eddy current proximity switch. When an alternating current is passed thru this coil, an alternative magnetic field is generated. If a metal object comes in the close proximity of the coil, then eddy currents are induced in the object due to the magnetic field. These eddy currents create their own magnetic field which distorts the magnetic field responsible for their generation.

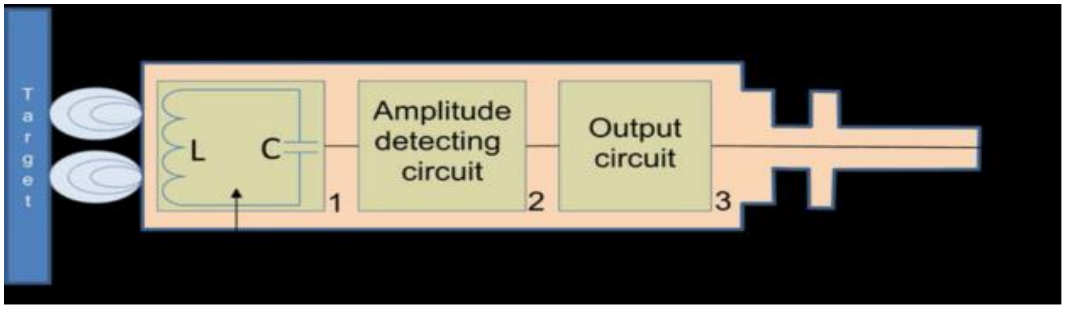


Figure 4.6 **Eddy current proximity sensors**

2. Inductive proximity switch

Inductive proximity switches are basically used for detection of metallic objects. Figure shows the construction of inductive proximity switch. An inductive proximity sensor has four components; the coil, oscillator, detection circuit and output circuit. An alternating

current is supplied to the coil which generates a magnetic field. When, a metal object comes closer to the end of the coil, inductance of the coil changes. This is continuously monitored by a circuit which triggers a switch when a preset value of inductance change is occurred.

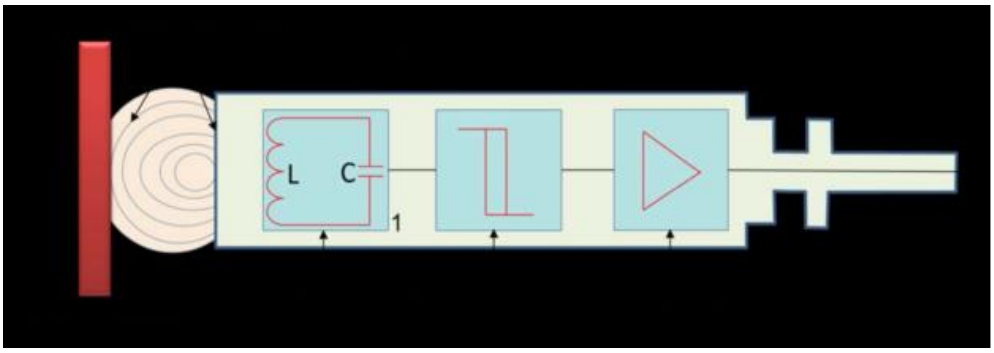


Figure 4.7 Inductive proximity switch

3.Opticalencoders

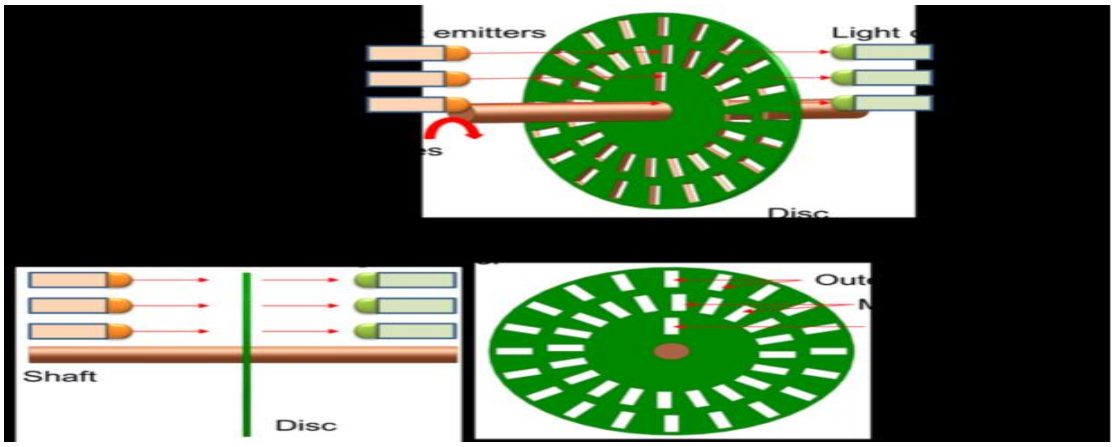


Figure Optical encoders

3. Pneumatic Sensors

Pneumatic sensors are used to measure the displacement as well as to sense the proximity of an object close to it. The displacement and proximity are transformed into change in air pressure. Figure shows a schematic of construction and working of such a sensor. It comprises of three ports. Low pressure air is allowed to escape through port A. In the absence of any obstacle / object, this low pressure air escapes and in doing so, reduces the pressure in the port B. However when an object obstructs the low pressure

air (Port A), there is rise in pressure in output port B. This rise in pressure is calibrated to measure the displacement or to trigger a switch. These sensors are used in robotics, pneumatics and for tooling in CNC machine tools.

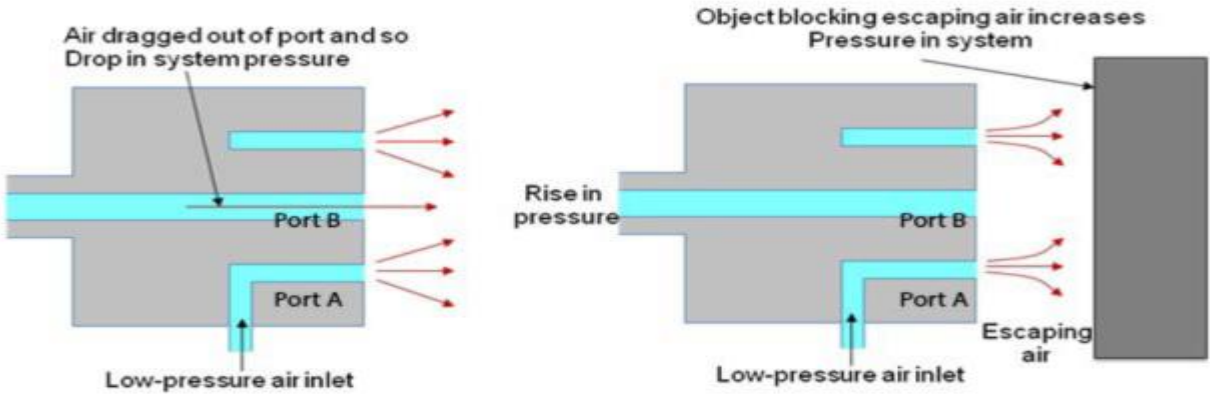


Figure 4.8 Pneumatic sensors

5. Proximity Switches

Figure shows a number of configurations of contact-type proximity switch being used in manufacturing automation. These are small electrical switches which require physical contact and a small operating force to close the contacts. They are basically employed on conveyor systems to detect the presence of an item on the conveyor belt.

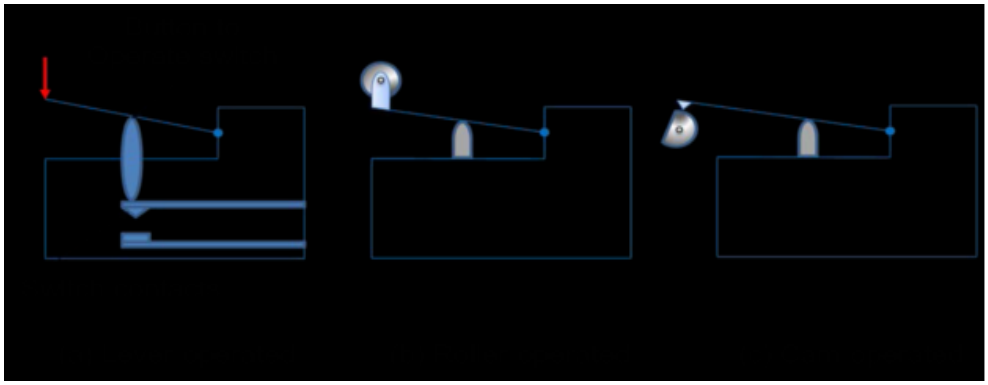


Figure 4.9 Proximity Switches

6. Hall effect sensor

Figure shows the principle of working of Hall effect sensor. Hall effect sensors work on the principle that when a beam of charge particles passes through a magnetic field, forces act on the particles and the current beam is deflected from its straight line path.

Thus one side of the disc will become negatively charged and the other side will be of positive charge. This charge separation generates a potential difference which is the measure of distance of magnetic field from the disc carrying current.

The typical application of Hall effect sensor is the measurement of fluid level in a container. The container comprises of a float with a permanent magnet attached at its top. An electric circuit with a current carrying disc is mounted in the casing. When the fluid level increases, the magnet will come close to the disc and a potential difference generates. This voltage triggers a switch to stop the fluid to come inside the container.

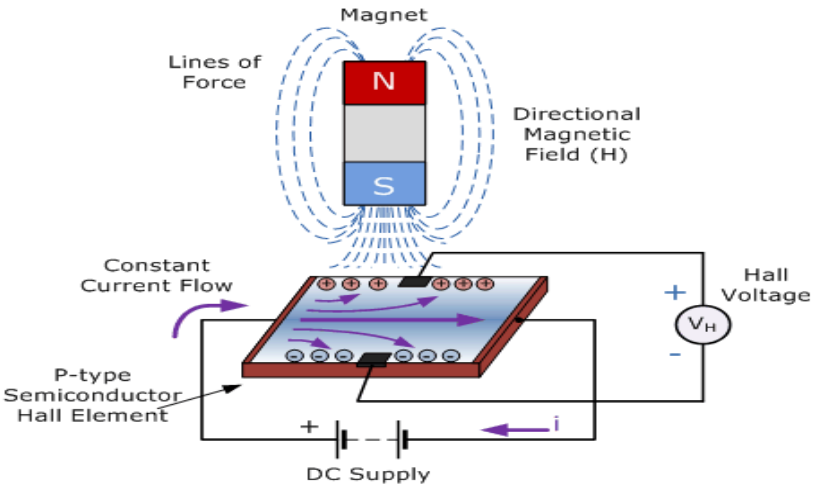


Figure 4.10 Hall effect sensor

4.3. Sensors and signal processing

4.3.1. Velocity, motion, force and pressure sensors

1. Tachogenerator

Tachogenerator works on the principle of variable reluctance. It consists of an assembly of a toothed wheel and a magnetic circuit as shown in figure. Toothed wheel is mounted on the shaft or the element of which angular motion is to be measured. Magnetic circuit comprising of a coil wound on a ferromagnetic material core. As the wheel rotates, the air gap between wheel tooth and magnetic core changes which results in cyclic change in flux linked with the coil. The alternating emf generated is the measure of angular motion. A pulse shaping signal conditioner is used to transform the output into a number of pulses which can be counted by a counter.

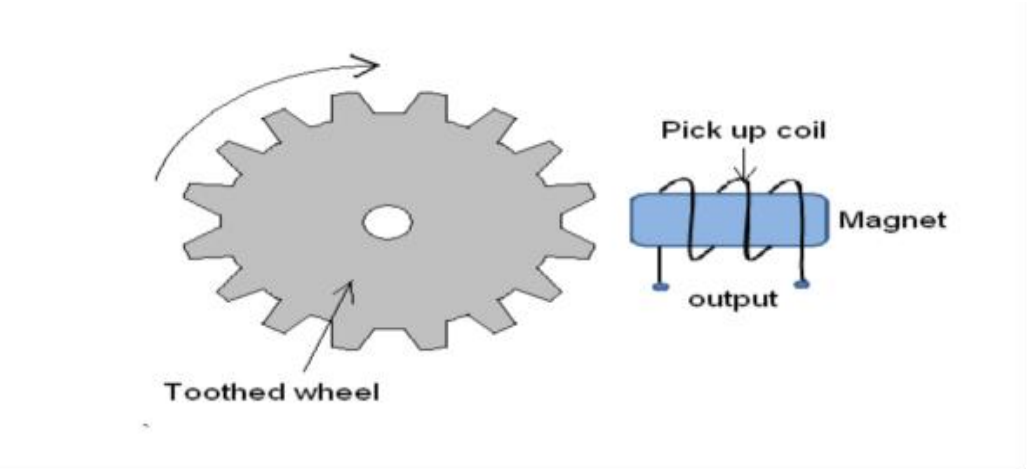


Figure 4.11.Tachogenerator

2. Pyroelectric sensors

These sensors work on the principle of *pyroelectricity*, which states that a crystal material such as Lithium tantalite generates charge in response to heat flow. In presence of an electric field, when such a crystal material heats up, its electrical dipoles line up as shown in figure 2.4.3. This is called as polarization. On cooling, the material retains its polarization. In absence of electric field, when this polarized material is subjected to infra red irradiation, its polarization reduces. This phenomenon is the measure of detection of movement of an object.

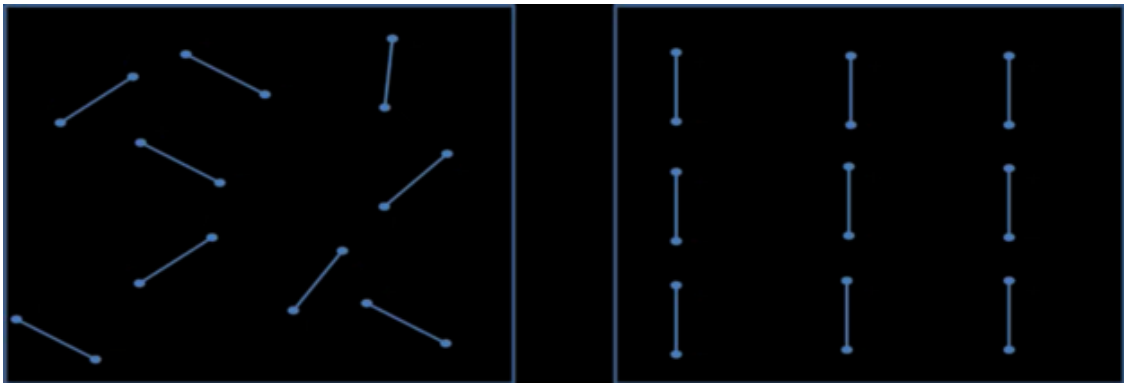


Figure 4.12. Pyroelectric sensors

3. Strain Gauge as force Sensor

Strain gauge based sensors work on the principle of change in electrical resistance. When, a mechanical element subjects to a tension or a compression the electric

resistance of the material changes. This is used to measure the force acted upon the element.

Figure shows a strain gauge load cell. It comprises of cylindrical tube to which strain gauges are attached. A load applied on the top collar of the cylinder compress the strain gauge element which changes its electrical resistance. Generally strain gauges are used to measure forces up to 10 MN. The non-linearity and repeatability errors of this transducer are ±0.03% and ±0.02% respectively.

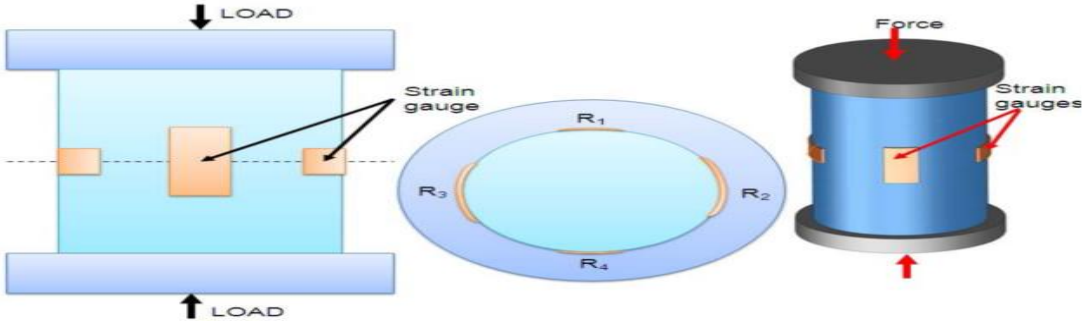


Figure 4.13 Strain Gauge as force Sensor

4. Fluid pressure

Chemical, petroleum, power industry often need to monitor fluid pressure. Various types of instruments such as diaphragms, capsules, and bellows are used to monitor the fluid pressure. Specially designed strain gauges doped in diaphragms are generally used to measure the inlet manifold pressure in applications such as automobiles. A typical arrangement of strain gauges on a diaphragm is shown in figure 2.4.6. Application of pressurized fluid displaces the diaphragm. This displacement is measured by the stain gauges in terms of radial and/or lateral strains. These strain gauges are connected to form the arms of a Wheatstone bridge.

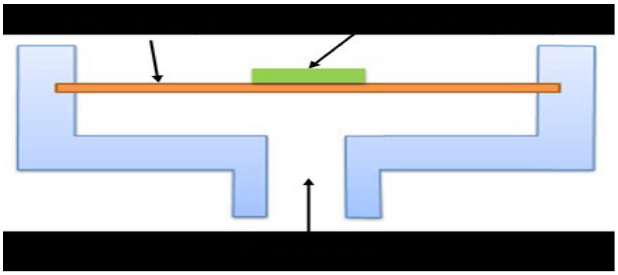


Figure 1.14. Fluid pressure

5. Tactile sensors

In general, tactile sensors are used to sense the contact of fingertips of a robot with an object. They are also used in manufacturing of 'touch display' screens of visual display units (VDUs) of CNC machine tools. Figure 2.4.9 shows the construction of piezo-electric polyvinylidene fluoride (PVDF) based tactile sensor. It has two PVDF layers separated by a soft film which transmits the vibrations. An alternating current is applied to lower PVDF layer which generates vibrations due to reverse piezoelectric effect. These vibrations are transmitted to the upper PVDF layer via soft film. These vibrations cause alternating voltage across the upper PVDF layer.

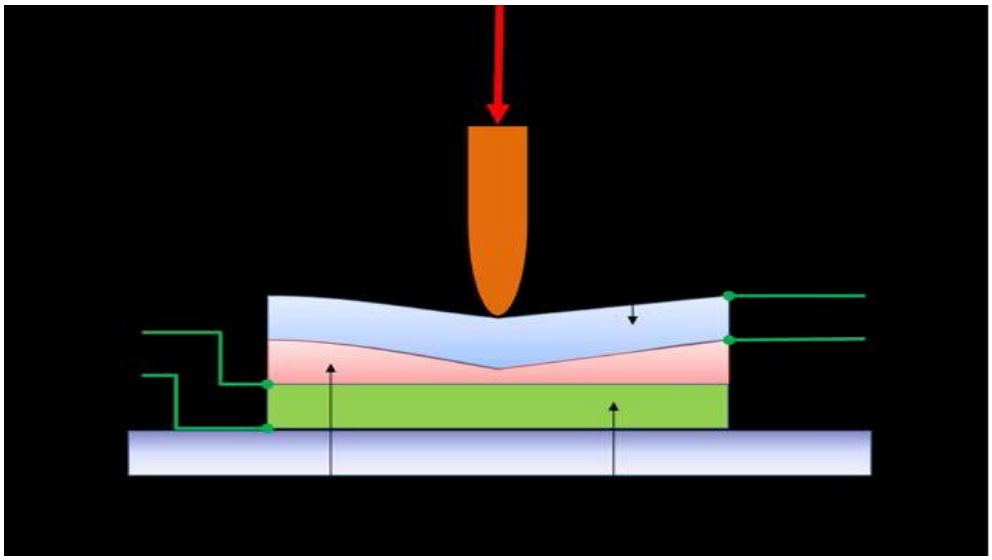


Figure 4.15. Tactile sensors

6. Piezoelectric sensor

Piezoelectric sensor is used for the measurement of pressure, acceleration and dynamic-forces such as oscillation, impact, or high speed compression or tension. It contains piezoelectric ionic crystal materials such as Quartz (Figure 2.4.10). On application of force or pressure these materials get stretched or compressed. During this process, the charge over the material changes and redistributes. One face of the material becomes positively charged and the other negatively charged. The net charge q on the surface is proportional to the amount x by which the charges have been displaced. The displacement is proportion to force. Therefore we can write,

$q = kx = SF$ (2.4.1)

where k is constant and S is a constant termed the charge sensitivity.

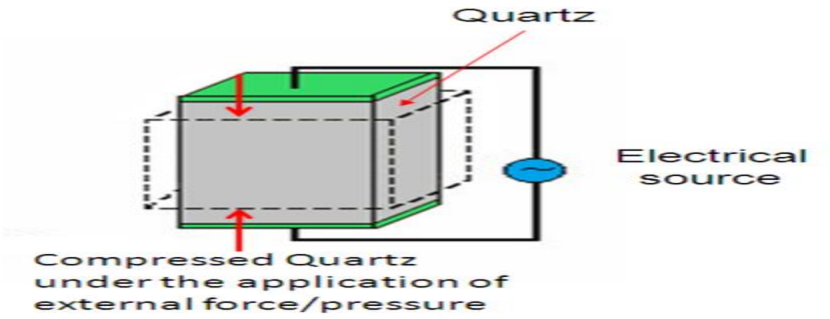


Figure 4.16. Piezoelectric sensor

7. Temperature sensors

Temperature conveys the state of a mechanical system in terms of expansion or contraction of solids, liquids or gases, change in electrical resistance of conductors, semiconductors and thermoelectric emfs. Temperature sensors such as bimetallic strips, thermocouples, thermistors are widely used in monitoring of manufacturing processes such as casting, molding, metal cutting etc. The construction details and principle of working of some of the temperature sensors are discussed in following sections.

8. Bimetallic strips

Bimetallic strips are used as thermal switch in controlling the temperature or heat in a manufacturing process or system. It contains two different metal strips bonded together. The metals have different coefficients of expansion. On heating the strips bend into curved strips with the metal with higher coefficient of expansion on the outside of the curve. Figure shows a typical arrangement of a bimetallic strip used with a setting-up magnet. As the strips bend, the soft iron comes in closer proximity of the small magnet and further touches. Then the electric circuit completes and generates an alarm. In this way bimetallic strips help to protect the desired application from heating above the pre-set value of temperature.

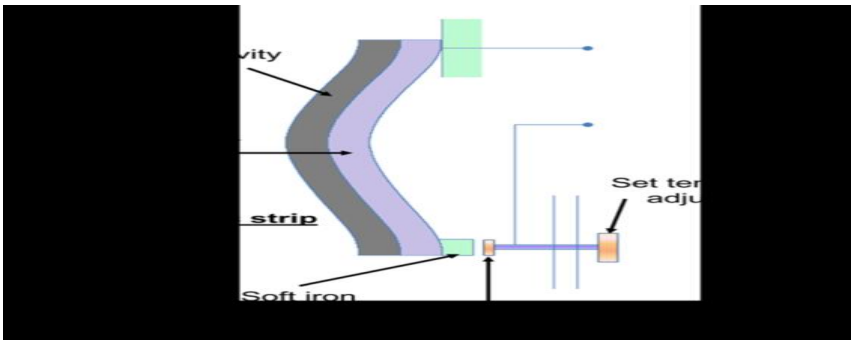


Figure 4.17. Bimetallic strips

9. Resistance temperature detectors (RTDs)

RTDs work on the principle that the electric resistance of a metal changes due to change in its temperature. On heating up metals, their resistance increases and follows a linear relationship as shown in Figure 2.5.2. The correlation is

$Rt = R0\ (1 + \alpha T)$ (2.5.1)

where Rt is the resistance at temperature T (^{0}C) and $R0$ is the temperature at 0^{0}C and α is the constant for the metal termed as temperature coefficient of resistance. The sensor is usually made to have a resistance of 100 Ω at 0 °C

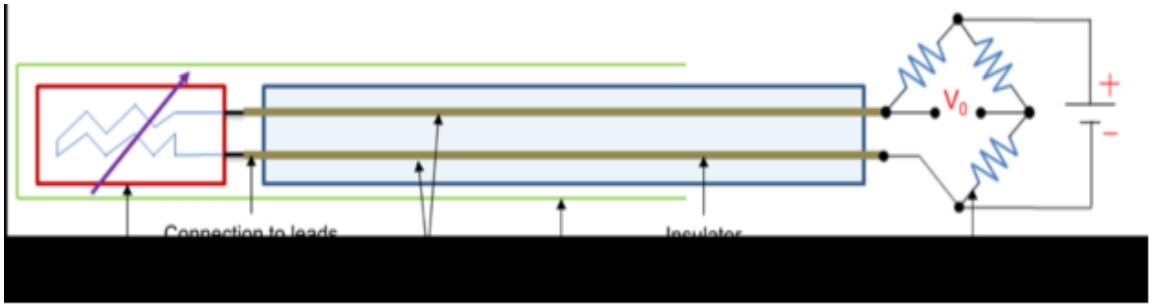


Figure 4.18. Resistance temperature detectors (rtds)

Figure the construction of a RTD. It has a resistor element connected to a Wheatstone bridge. The element and the connection leads are insulated and protected by a sheath. A small amount of current is continuously passing though the coil. As the temperature changes the resistance of the coil changes which is detected at the Wheatstone bridge

10. Thermistors

Thermistors follow the principle of decrease in resistance with increasing temperature. The material used in thermistor is generally a semiconductor material such as a sintered metal oxide (mixtures of metal oxides, chromium, cobalt, iron, manganese and nickel) or doped polycrystalline ceramic containing barium titanate (BaTiO3) and other compounds. As the temperature of semiconductor material increases the number of electrons able to move about increases which results in more current in the material and reduced resistance. Thermistors are rugged and small in dimensions. They exhibit nonlinear response characteristics.

Thermistors are available in the form of a bead (pressed disc), probe or chip. Figure shows the construction of a bead type thermistor. It has a small bead of dimension from

0.5 mm to 5 mm coated with ceramic or glass material. The bead is connected to an electric circuit through two leads. To protect from the environment, the leads are contained in a stainless steel tube.

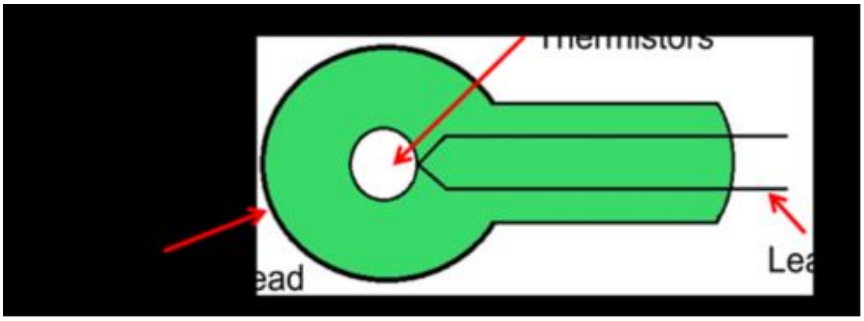


Figure 4.19. Thermistors

11. Thermocouple

Thermocouple works on the fact that when a junction of dissimilar metals heated, it produces an electric potential related to temperature. As per Thomas Seebeck (1821), when two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, then there is a continuous current which flows in the thermoelectric circuit. Figure 2.5.5 shows the schematic of thermocouple circuit. The net open circuit voltage (the Seebeck voltage) is a function of junction temperature and composition of two metals. It is given by,

$\Delta V_{AB} = \alpha \Delta T$ (2.5.2)

where α, the Seebeck coefficient, is the constant of proportionality

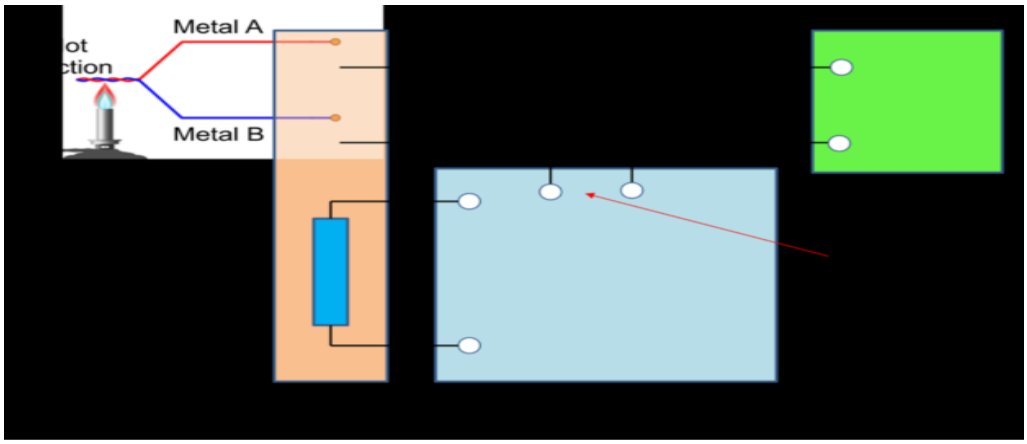


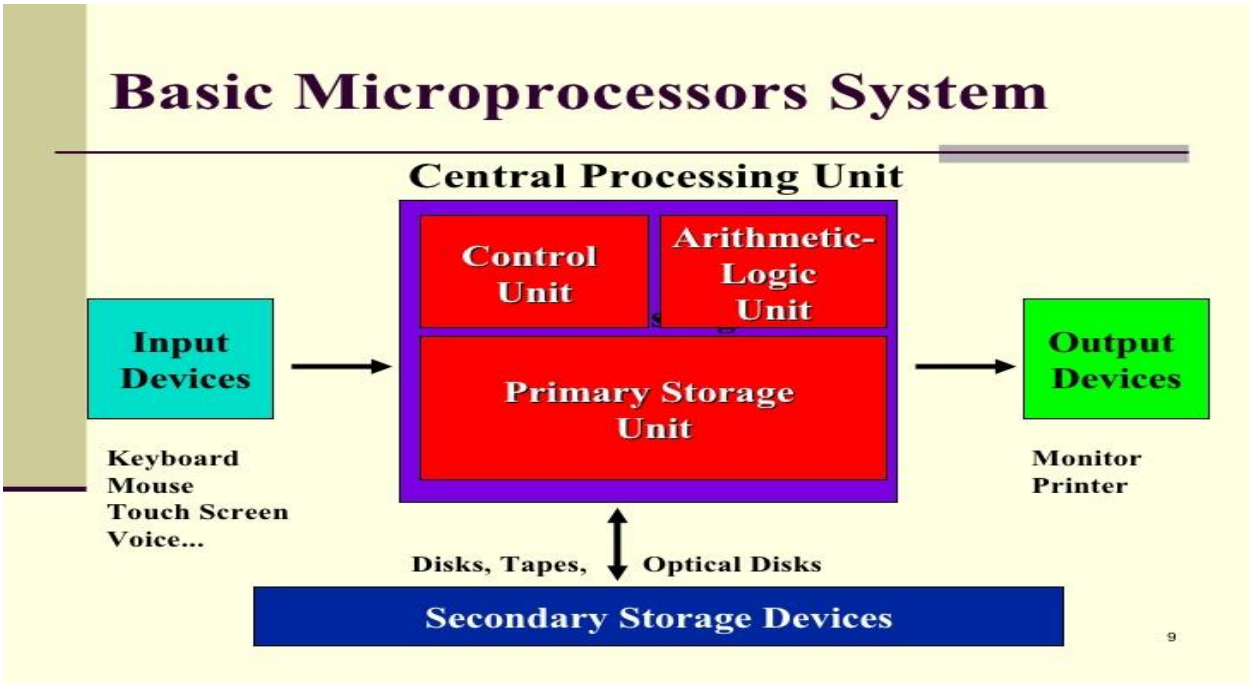
Figure 4.20.Thermocouple

4.3. Basic Microprocessor and computer Applications

A **microprocessor** is a computer processor which incorporates the functions of a computer's central processing unit (CPU) on a single integrated circuit (IC), or at most a few integrated circuits. The microprocessor is a multipurpose, clock driven, register based, digital-integrated circuit which accepts binary data as input, processes it according to instructions stored in its memory, and provides results as output. Microprocessors contain both combinational logic and sequential digital logic. Microprocessors operate on numbers and symbols represented in the binary numeral system.

The integration of a whole CPU onto a single chip or on a few chips greatly reduced the cost of processing power, increasing efficiency. Integrated circuit processors are produced in large numbers by highly automated processes resulting in a low per unit cost. Single-chip processors increase reliability as there are many fewer electrical connections to fail. As microprocessor designs get better, the cost of manufacturing a chip (with smaller components built on a semiconductor chip the same size) generally stays the same.

Before microprocessors, small computers had been built using racks of circuit boards with many medium- and small-scale integrated circuits . Microprocessors combined this into one or a few large-scale ICs. Continued increases in microprocessor capacity have since rendered other forms of computers almost completely obsolete (see history of computing hardware), with one or more microprocessors used in everything from the smallest embedded systems and handheld devices to the largest mainframes and supercomputer.



The arithmetic logic unit (ALU), which performs simple arithmetic and logical operations. The control unit (CU), which manages the various components of the computer.

It reads and interprets instructions from memory and transforms them into a series of signals to activate other parts of the computer. The control unit calls upon the arithmetic logic unit to perform the necessary calculations.

- A CPU conducts all the mathematic and logic operations.

Arithmetic logic unit (ALU) is composed of :- Combinational logic & sequential logic circuit .Before the circuit we must know about digital logic. Digital logic is the application of the Boolean algebra of 0 and 1 to electronic hardware consisting of logic gates connected to form a circuit diagram. Each gate implements a Boolean operation, and is depicted schematically by a shape indicating the operation. The shapes associated with the gates for conjunction (AND-gates), disjunction (OR-gates), and complement (inverters) are as follows.

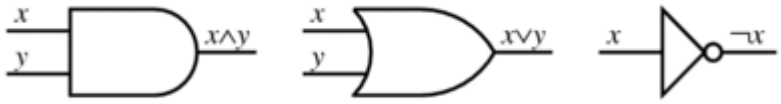


Figure 3. Logic gates

The lines on the left of each gate represent input wires or *ports*. The value of the input is represented by a voltage on the lead. For so-called "active-high" logic, 0 is represented by a voltage close to zero or "ground", while 1 is represented by a voltage close to the supply voltage; active-low reverses this. The line on the right of each gate represents the output port, which normally follows the same voltage conventions as the input ports.

Complement is implemented with an inverter gate. The triangle denotes the operation that simply copies the input to the output; the small circle on the output denotes the actual inversion complementing the input. The convention of putting such a circle on any port means that the signal passing through this port is complemented on the way through, whether it is an input or output port. Complementing all three ports of an AND gate converts it to an OR gate and vice versa, as shown in Figure 4 below. Complementing both ports of an inverter however leaves the operation unchanged.

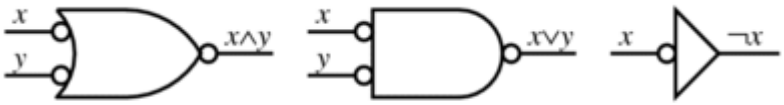


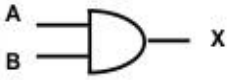
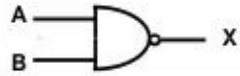
Figure 4. De Morgan equivalents

More generally one may complement any of the eight subsets of the three ports of either an AND or OR gate. The resulting sixteen possibilities give rise to only eight Boolean operations, namely those with an odd number of 1's in their truth table. There are eight such because the "odd-bit-out" can be either 0 or 1 and can go in any of four positions in the truth table. There being sixteen binary Boolean operations, this must leave eight operations with an even number of 1's in their truth tables. Two of these are the constants 0 and 1 (as binary operations that ignore both their inputs); four are the operations that depend nontrivially on exactly one of their two inputs, namely x, y, $\neg x$, and $\neg y$; and the remaining two are $x \oplus y$ (XOR) and its complement $x \equiv y$.

Table 4.1 combination gates

Digital Logic Circuits 4 *Logic Gates*

COMBINATIONAL GATES

Name	Symbol	Function	Truth Table
AND		X = A • B or X = AB	A B | X 0 0 | 0 0 1 | 0 1 0 | 0 1 1 | 1
OR		X = A + B	A B | X 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 1
I		X = A	A | X 0 | 1 1 | 0
Buffer		X = A	A | X 0 | 0 1 | 1
NAND		X = (AB)'	A B | X 0 0 | 1 0 1 | 1 1 0 | 1 1 1 | 0
NOR		X = (A + B)'	A B | X 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 0
XOR Exclusive OR		X = A ⊕ B or X = A'B + AB'	A B | X 0 0 | 0 0 1 | 1 1 0 | 1 1 1 | 0
XNOR Exclusive NOR or Equivalence		X = (A ⊕ B)' or X = A'B'+ AB	A B | X 0 0 | 1 0 1 | 0 1 0 | 0 1 1 | 1

Computer Organization *Computer Architectures Lab*

4.3.1. What are Digital Logic Circuits?

The digital logic circuits are basic building blocks of the digital systems (digital computers). These digital logic circuits can be classified into two categories such as combinational logic circuits and sequential logic circuits.

Figure 4. 21.basic building blocks of the digital systems

Combinational Logic Circuits

The simple time independent logic circuits that are implemented using Boolean circuits whose output logic value depends only on the input logic values can be called as **combinational logic circuits.**

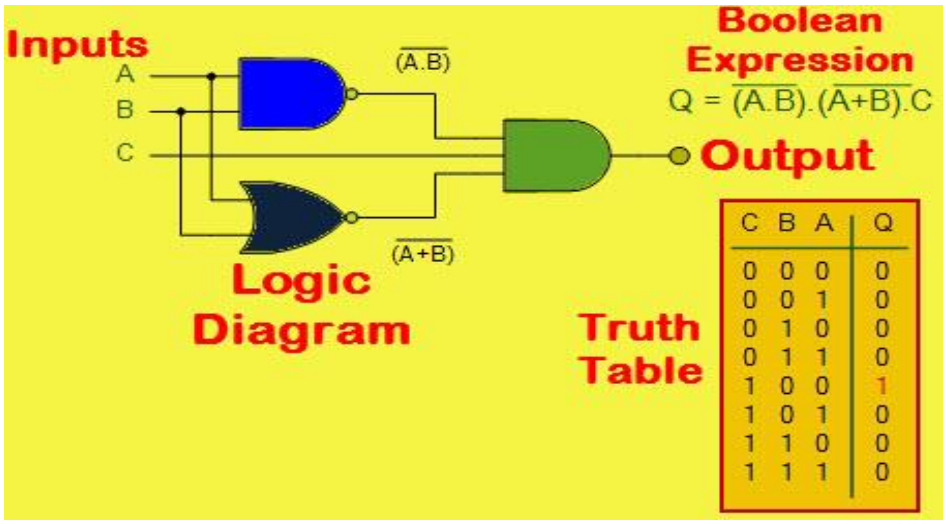


FIgure 4.22. Combinational Logic Circuits

Combinational Logic Circuit

The figure shows all the three major components of the combinational logic circuit such as logic diagram, truth table, and Boolean expression. The digital logic circuits whose outputs can be determined using the logic function of current state input are combinational logic circuits, hence, these are also called as time independent logic circuits.

Thus, these combinational digital logic circuits don't have the capability to store a state inside them.

Hence, the combinational logic circuits do not contain any memory elements.

The arithmetic operations performed on the date stored data in the computers are done using combinational logic circuits.

The combinational digital logic circuits are fundamentally implemented using different types of devices such as multiplexers, DE multiplexers, encoders, decoders, half adder, and full adders.

The components of arithmetic and logic unit of the computers are generally comprised of combinational digital logic circuits.

The independent working states of the combinational logic circuits are represented with Boolean algebra and after simplification by using NOR, NOT, and NAND gates the circuit can be implemented.

The combinational digital circuits don't require any feedbacks.

The combinational logic circuits are independent of the clock.

As there are no clocks used in these digital logic circuits, they do not need any triggering.

The combinational logic circuit's behavior can be defined by using the set of output functions.

In general, sum of products or products of sums method is used for the construction of combinational logic.

sequential Logic Circuits

The simple logic circuits whose output logic value depends on the input logic values and also on the stored information is called as sequential logic circuits.

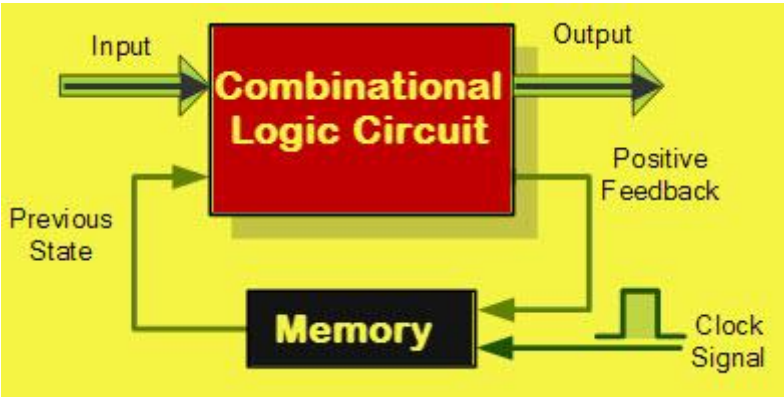


Figure 4.22. Sequential Logic Circuit

Sequential Logic Circuit

The figure represents the block diagram of the sequential logic circuit.

Sequential Logic Circuits

The digital logic circuits whose outputs can be determined using the logic function of current state inputs and past state inputs are called as sequential logic circuits.

These sequential digital logic circuits are capable to retain the earlier state of the system based on the current inputs and earlier state.

Hence, unlike the combinational logic circuits, these sequential digital logic circuits are capable of storing the data in a digital circuit.

The sequential logic circuits contain memory elements.

The latch is considered as the simplest element used to retain the earlier memory or state in the sequential digital logic.

Latches can also be called as flip-flops, but, if we consider the true structural form, then it can be considered as a combinational circuit with one or more than one outputs fed back as inputs.

These sequential digital logic circuits are used in maximum types of memory elements and also in finite state machines, which are digital circuit models with finite possible states.

The maximum number of sequential logic circuits uses a clock for triggering the flip flops operation.

If the flip flop in the digital logic circuit is triggered, then the circuit is called as synchronous sequential circuit and the other circuits (which are simultaneously not triggered) are called as asynchronous sequential circuits.

The sequential digital logic circuits utilize the feedbacks from outputs to inputs.

The sequential logic circuit's behavior can be defined by using the set of output functions and set of next state or memory functions.

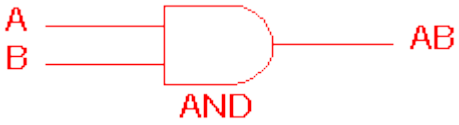
In practical digital logic circuits, combinational digital logic circuits and sequential digital logic circuits are used.

4.3.1.1. Digital logic Gate and Truth tables

A Digital Logic Gate is an electronic circuit which makes logical decisions based on the combination of digital signals present on its inputs. Digital logic gates can have more than one input, for example, inputs A, B, C, D etc., but generally only have one digital output, (Q).

Digital systems are said to be constructed by using logic gates. These gates are the AND, OR, NOT, NAND, NOR, EXOR and EXNOR gates. The basic operations are described below with the aid of truth tables.

AND gate



2 Input AND gate		
A	B	A.B
0	0	0
0	1	0
1	0	0
1	1	1

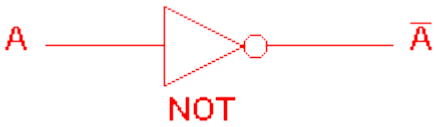
The AND gate is an electronic circuit that gives a high output (1) only if all its inputs are high. A dot (.) is used to show the AND operation i.e. A.B. Bear in mind that this dot is sometimes omitted i.e. AB

OR gate

2 Input OR gate		
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

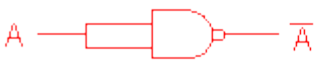
The OR gate is an electronic circuit that gives a high output (1) if one or more of its inputs are high. A plus (+) is used to show the OR operation.

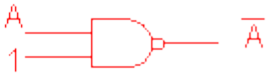
NOT gate



NOT gate	
A	$\overline{A}$
0	1
1	0

The NOT gate is an electronic circuit that produces an inverted version of the input at its output. It is also known as an inverter. If the input variable is A, the inverted output is known as NOT A. This is also shown as A', or A with a bar over the top, as shown at the outputs. The diagrams below show two ways that the NAND logic gate can be configured to produce a NOT gate. It can also be done using NOR logic gates in the same way.



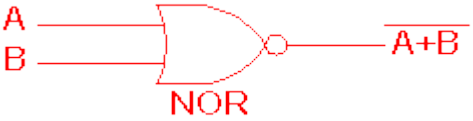


NAND gate

2 Input NAND gate		
A	B	$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

This is a NOT-AND gate which is equal to an AND gate followed by a NOT gate. The outputs of all NAND gates are high if any of the inputs are low. The symbol is an AND gate with a small circle on the output. The small circle represents inversion.

NOR gate



2 Input NOR gate		
A	B	$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

This is a NOT-OR gate which is equal to an OR gate followed by a NOT gate. The outputs of all NOR gates are low if any of the inputs are high.

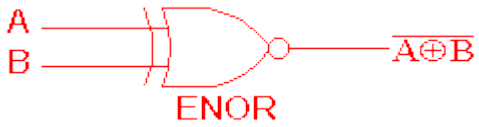
The symbol is an OR gate with a small circle on the output. The small circle represents inversion.

EXOR gate

2 Input EXOR gate		
A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

The 'Exclusive-OR' gate is a circuit which will give a high output if either, but not both, of its two inputs are high. An encircled plus sign (⊕) is used to show the EOR operation.

EXNOR gate



2 Input EXNOR gate		
A	B	$\overline{A \oplus B}$
0	0	1
0	1	0
1	0	0
1	1	1

The 'Exclusive-NOR' gate circuit does the opposite to the EOR gate. It will give a low output if either, but not both, of its two inputs are high. The symbol is an EXOR gate with a small circle on the output. The small circle represents inversion.

The NAND and NOR gates are called universal functions since with either one the AND and OR functions and NOT can be generated.

Note:A function in sum of products form can be implemented using NAND gates by replacing all AND and OR gates by NAND gates.

A function in product of sums form can be implemented using NOR gates by replacing all AND and OR gates by NOR gates.

Table 4.2 : Logic gate symbols

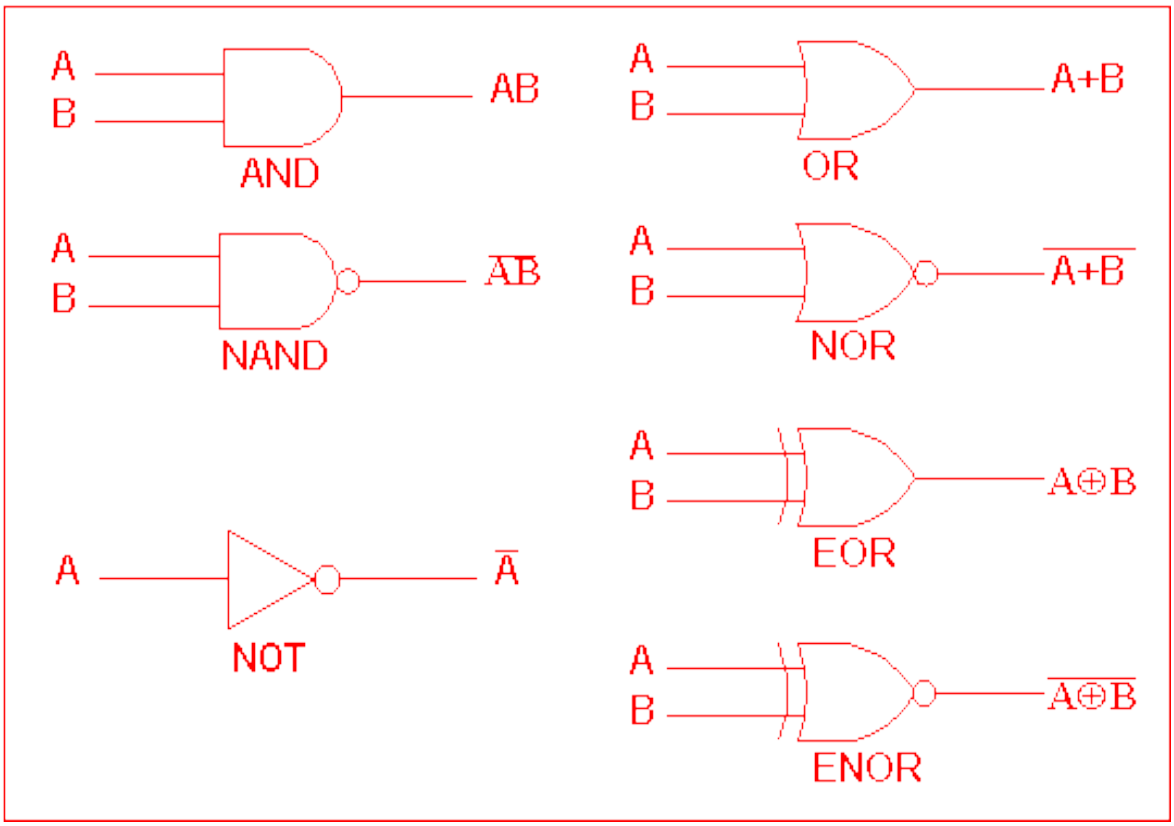


Table 4.3 is a summary truth table of the input/output combinations for the NOT gate together with all possible input/output combinations for the other gate functions. Also note that a truth table with 'n' inputs has 2n rows. You can compare the outputs of different gates.

Table 4.3 : Logic gates representation using the Truth table

NOT gate	
A	$\overline{A}$
0	1
1	0

INPUTS		OUTPUTS					
A	B	AND	NAND	OR	NOR	EXOR	EXNOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

Example

A NAND gate can be used as a NOT gate using either of the following wiring configurations.

We need to produce the appropriate output from the possible combinations of inputs, which we achieve using logic gates. Table 4.2 shows the symbols for eight logic gates, some or all of which you may recognise.

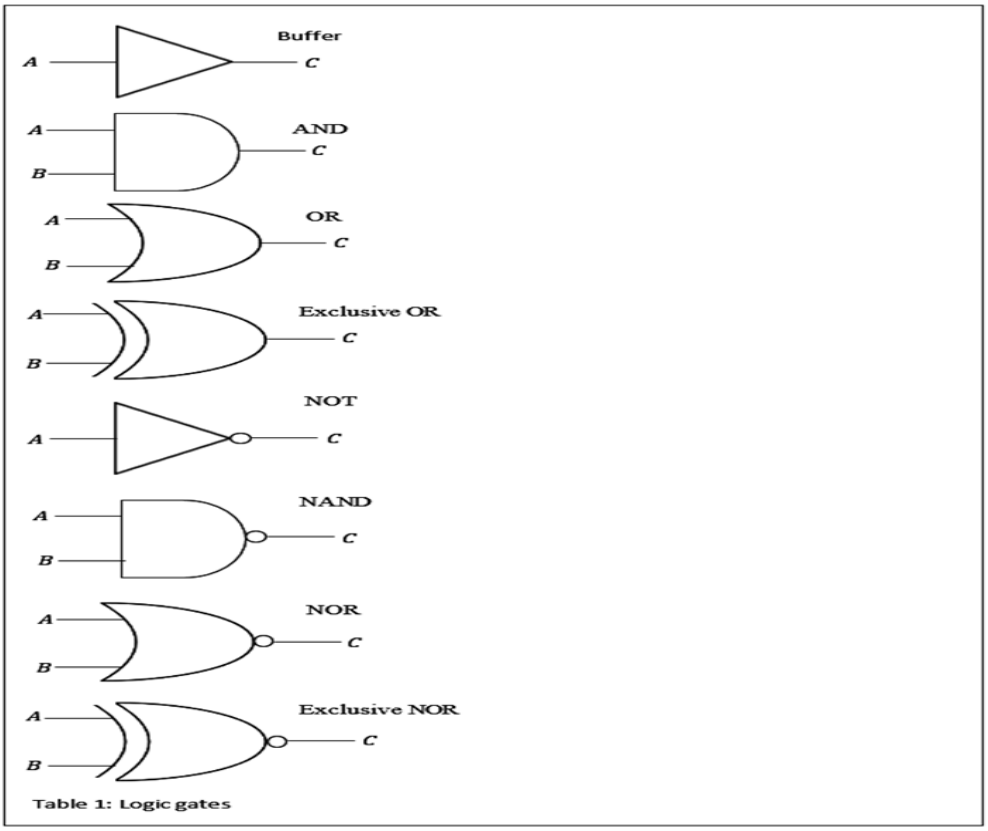


Table 4.3 : Logic Gates

4.4. Programmable Logic Controllers (PLCs): Basics, Types & Application

4.4.1. What is a PLC?

PLC stands for “Programmable Logic Controller”. A PLC is a computer specially designed to operate reliably under harsh industrial environments – such as extreme temperatures, wet, dry, and/or dusty conditions. PLCs are used to automate industrial processes such as a manufacturing plant’s assembly line, an ore processing plant, or a wastewater treatment plant.

PLCs share many features of the personal computer you have at home. They both have a power supply, a CPU (Central Processing Unit), inputs and outputs (I/O), memory, and operating software (although it’s a different operating software).

The biggest differences are that a PLC can perform discrete and continuous functions that a PC cannot do, and a PLC is much better suited to rough industrial environments. A PLC can be thought of as a ‘ruggedized’ digital computer that manages the electromechanical processes of an industrial environment.

PLCs play a crucial role in the field of automation, using forming part of a larger SCADA (Supervisory Control and Data Acquisition) system. A PLC can be programmed according to the operational requirement of the process. In the manufacturing industry, there will be a need for reprogramming due to the change in the nature of production. To overcome this difficulty, PLC-based control systems were introduced. We’ll first discuss PLC basics before looking at various applications of PLCs.

PLC Basics

PLCs were invented by Dick Morley in 1964. Since then PLC has revolutionized the industrial and manufacturing sectors. There is a wide range of PLC functions like timing, counting, calculating, comparing, and processing various analog signals.

The main advantage of PLC over a “hard-wired” control system is that you can go back and change a PLC after you’ve programmed it, at little cost (just the cost of the programmer’s time). In a hard-wired control system, you essentially have to rip out wires and start from scratch (which is more expensive and takes longer). Let’s look at an example to better understand this advantage.

Imagine you have a light connected to a switch. In general, the light operates under two conditions – ON and OFF. Now you are given a task that when you turn ON the switch, the light should glow only after 30 seconds. With this hard-wired setup – we're stuck. The only way to achieve this is to completely rewire our circuit to add a timing relay. That's a lot of hassle for a minor change.

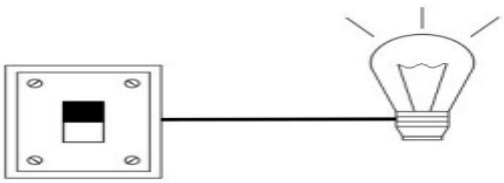


Figure 4.21. Light Switch

This is where a programmable logic controller comes into the picture, which doesn't require any additional wiring and hardware to make sure of a change. Rather it requires a simple change in code, programming the PLC to only turn on the light 30 seconds after the switch is turned ON. So, by using a PLC, it is easy to incorporate multiple inputs and outputs.

This is just a simple example – a PLC has the ability to control much larger and more complex processes. A PLC can be customized depending on the application and needs of the user.

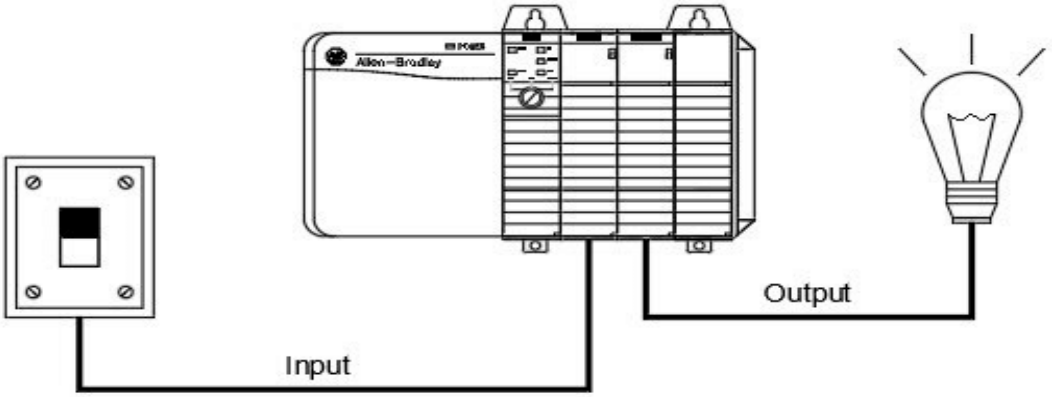


Figure 4.23. Light operated by a PLC

How Does a PLC work?

The working of a programmable logic controller can be easily understood as a cyclic scanning method known as the scan cycle.

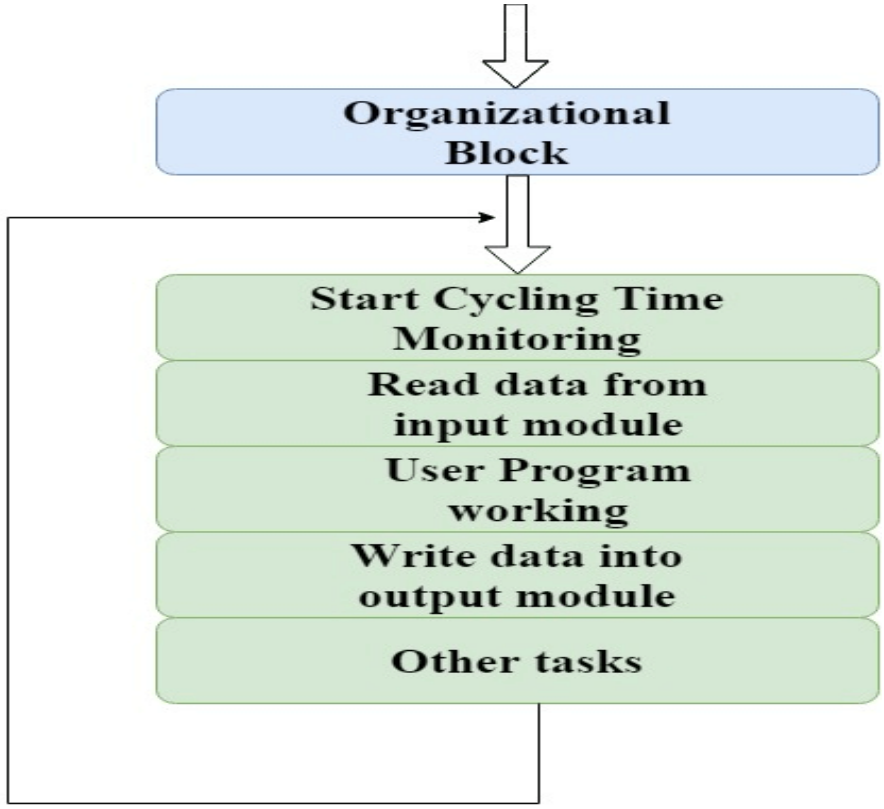


Figure 1.24. Block Diagram of How A PLC Works

A PLC Scan Process includes the following steps

The operating system starts cycling and monitoring of time.

- The CPU starts reading the data from the input module and checks the status of all the inputs.
- The CPU starts executing the user or application program written in relay-ladder logic or any other PLC-programming language.
- Next, the CPU performs all the internal diagnosis and communication tasks.
- According to the program results, it writes the data into the output module so that all outputs are updated.
- This process continues as long as the PLC is in run mode.

4.4.2. Physical Structure of PLC

The structure of a PLC is almost similar to a computer's architecture.

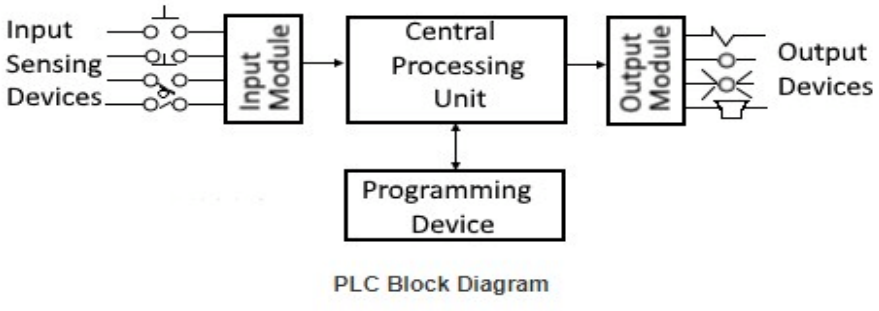


Figure4.25. PLC Block Diagram

Programmable Logic Controllers continuously monitors the input values from various input sensing devices (e.g. accelerometer, weight scale, hardwired signals, etc.) and produces corresponding output depending on the nature of production and industry. A typical block diagram of PLC consists of five parts namely:

- Rack or chassis
- Power Supply Module
- Central Processing Unit (CPU)
- Input & Output Module
- Communication Interface Module
- Rack or Chassis

In all PLC systems, the PLC rack or chassis forms the most important module and acts as a backbone to the system. PLCs are available in different shapes and sizes. When more complex control systems are involved, it requires larger PLC racks.

Small-sized PLC is equipped with a fixed I/O pin configuration. So, they have gone for modular type rack PLC, which accepts different types of I/O modules with sliding and fit in concept. All I/O modules will be residing inside this rack/chassis.

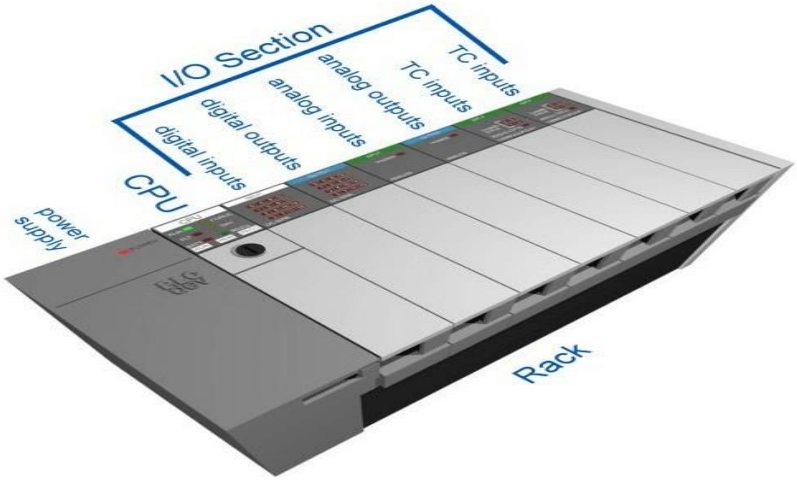


Figure4.26. Breakdown of PLC Rack

Power Supply Module

This module is used to provide the required power to the whole PLC system. It converts the available AC power to DC power which is required by the CPU and I/O module. PLC generally works on a 24V DC supply. Few PLC uses an isolated power supply.

CPU Module and Memory

CPU module has a central processor, ROM & RAM memory. ROM memory includes an operating system, drivers, and application programs. RAM memory is used to store programs and data. CPU is the brain of PLC with an octal or hexagonal microprocessor.

Being a microprocessor-based CPU, it replaces timers, relays, and counters. Two types of processors as a single bit or word processor can be incorporated with a PLC. One bit processor is used to perform logic functions. Whereas word processors are used for processing text, numerical data, controlling, and recording data.

CPU reads the input data from sensors, processes it, and finally sends the command to controlling devices. DC power source, as mentioned in the previous discussion is required voltage signals. CPU also contains other electrical parts to connect cables used by other units.

Input and Output Module

Have you ever thought about how to sense physical parameters like temperature, pressure, flow, etc? using PLC? Of course, PLC has an exclusive module for interfacing inputs and output, which is called an input & output module.

Input devices can be either start and stop pushbuttons, switches, etc and output devices can be an electric heater, valves, relays, etc. I/O module helps to interface input and output devices with a microprocessor. The input module of PLC is explained in the below figure.

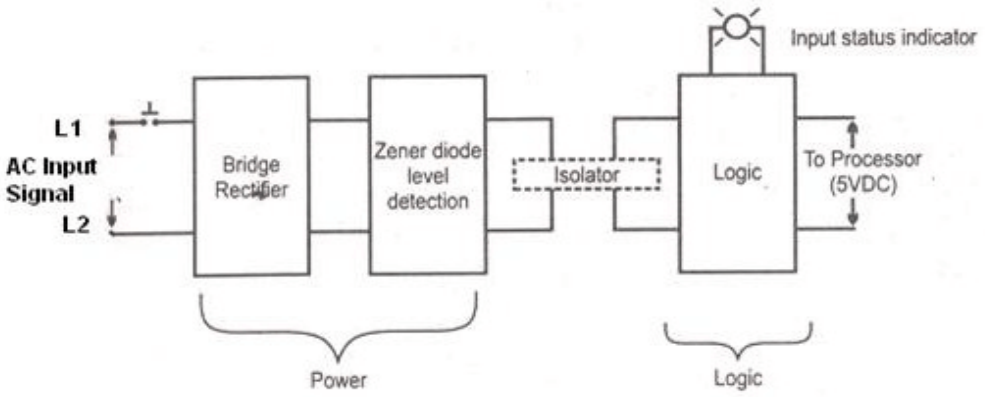


Figure 4.27. PLC Input Module

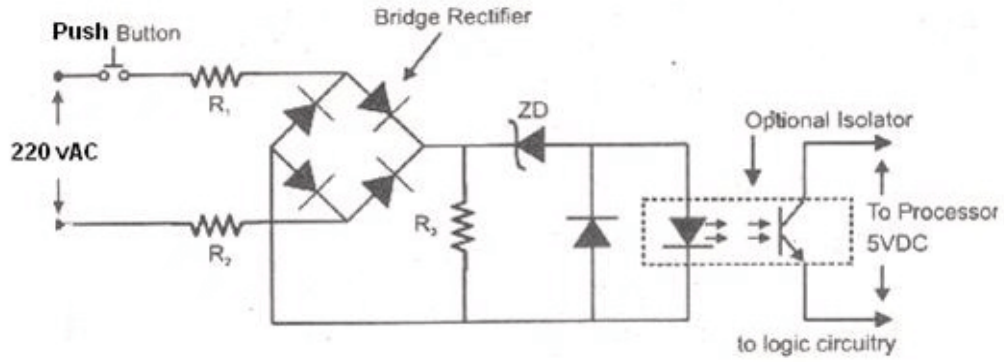


Figure 4.28.Diagram of PLC Input Module

The input module of PLC does four main functions.

Input module interface receives the signal from process devices at 220 V AC

Converts the input signal to 5 V DC that can be used by PLC

Isolator block is used to isolate/prevent PLC from undergoing fluctuation

After which the signal is sent to the output end i.e the PLC

There are two main sections in the input module namely the power section and the logical section. Both sections are electrically isolated from each other. Initially push

button is closed. So, 220 V AC supply is given to the bridge circuit through the resistors R1 and R2.

A bridge rectifier (such as a diode bridge rectifier) is used to convert the AC signal into DC and Zener diode is used to provide a low voltage supply to LED. When the light from LED falls on the phototransistor, it works in the conduction region. Finally, a 5V DC supply is given to the processor.

The output module of PLC works similarly to the input module but in the reverse process. It interfaces the output load and processor. So here the first section would be logic session and the power section comes next. The working of the output module is shown in the below figure

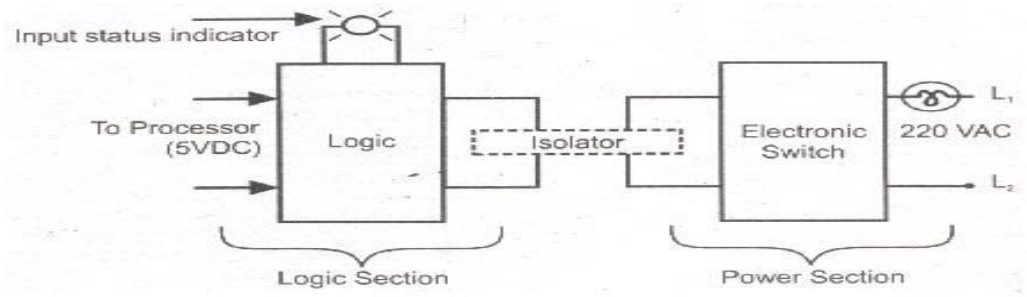


Figure 4.28.PLC Output Module

So, here when the program logic high signal is generated from the processor, LED will turn ON and allow the light to fall on a phototransistor. When the transistor goes to the conduction region, it generates a pulse to the gate of the Triac. The isolator block is used to isolate the logic section and control section.

Communication Interface Module

To transfer information between CPU and communication networks, intelligent I/O modules are used. These communication modules help to connect with other PLCs and computers which are placed at a remote location.

4.4.3. Types of PLCs

The two main types of PLC are fixed / compact PLC and modular PLC.

Compact PLC

Within a single case, there would be many modules. It has a fixed number of I/O modules and external I/O cards. So, it does not have the capability to expand the modules. Every input and output would be decided by the manufacturer.

Modular PLC

This type of PLC permits multiple expansion through “modules”, hence referred to as Modular PLC. I/O components can be increased. It is easier to use because each component is independent of each other.

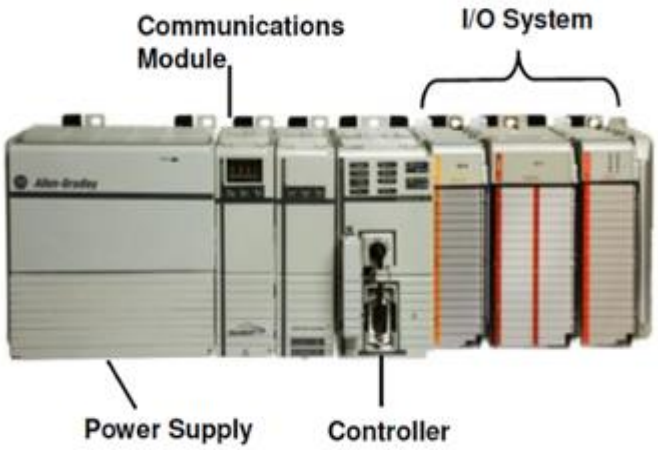


Figure 4.29. A Modular Type PLC

PLC are divided into three types based on output namely Relay output, Transistor output, and Triac Output PLC. The relay output type is best suited for both AC and DC output devices. Transistor output type PLC uses switching operations and used inside microprocessors.

According to the physical size, a PLC is divided into Mini, Micro, and Nano PLC.

Some of the manufacturers of PLCs include:

- Allen Bradley
- ABB
- Siemens
- Mitsubishi PLC
- Hitachi PLC
- Delta PLC
- General Electric (GE) PLC
- Honeywell PLC
- PLC Applications
- PLCs have a variety of applications and uses, including:
- Process Automation Plants (e.g. mining, oil &gas)

- Glass Industry
- Paper Industry
- Cement Manufacturing
- In boilers – Thermal Power Plants
- PLC Programming

When using a PLC, it's important to design and implement concepts depending on your particular use case. To do this we first need to know more about the specifics of PLC programming.

A PLC program consists of a set of instructions either in textual or graphical form, which represents the logic that governs the process the PLC is controlling. There are two main classifications of PLC programming languages, which are further divided into many sub-classified types.

- Textual Language
- Instruction list
- Structured text
- Graphical Form
- Ladder Diagrams (LD) (i.e. Ladder Logic)
- Function Block Diagram (FBD)
- Sequential Function Chart (SFC)

Although all of these PLC programming languages can be used to program a PLC, graphical languages (like ladder logic) are typically preferred to textual languages (like structured text programming).

Ladder Logic

Ladder logic is the simplest form of PLC programming. It is also known as "relay logic". The relay contacts used in relay controlled systems are represented using ladder logic. The below figure shows a simple example of a ladder diagram.

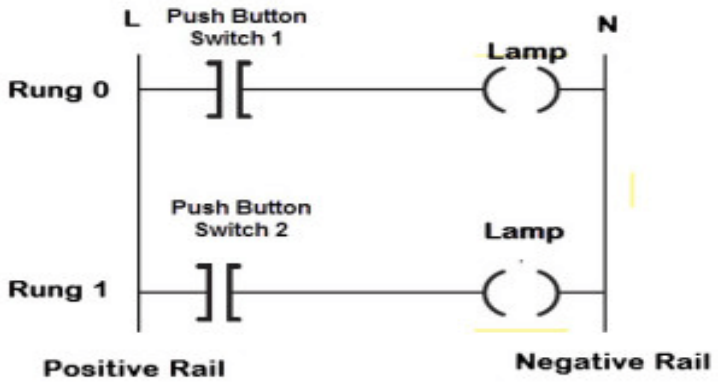


Figure 4.30.PLC Ladder Logic

In the above-mentioned example, two pushbuttons are used to control the same lamp load. When any one of the switches is closed, the lamp will glow.

The two horizontal lines are called rungs and the two vertical lines are called rails. Every rung forms the electrical connectivity between Positive rail (P) and Negative rail (N). This allows the current to flow between input and output devices.

Functional Block Diagrams

Functional Block Diagram (FBD) is a simple and graphical method to program multiple functions in PLC. PLCOpen has described using FBD in the standard IEC 61131-3. A function block is a program instruction unit that, when executed, yields one or more output values.

It is represented by a block as shown below. It is represented as a rectangular block with inputs entering on left and output lines leaving at the right. It gives a relation between the state of input and output

Figure 4.31.Function Block

The advantage of using FBD is that any number of inputs and outputs can be used on the functional block. When using multiple input and output, you can connect the output of one function block to the input of another. Whereby building a Function Block Diagram.

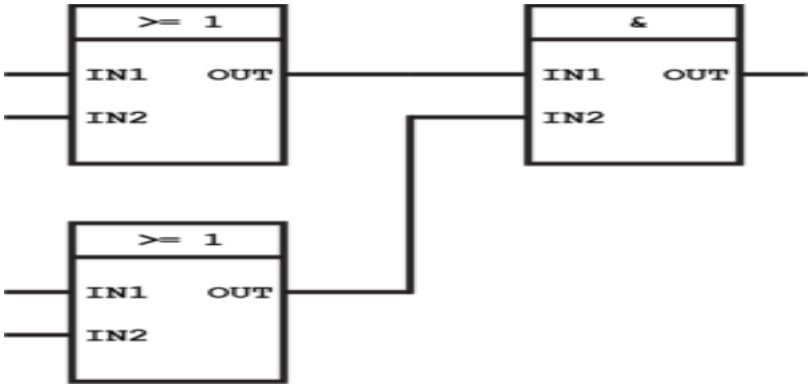


Figure Figure 4.32.Example Functional Block Diagram

The figure below shows various function blocks used in FBD programming.

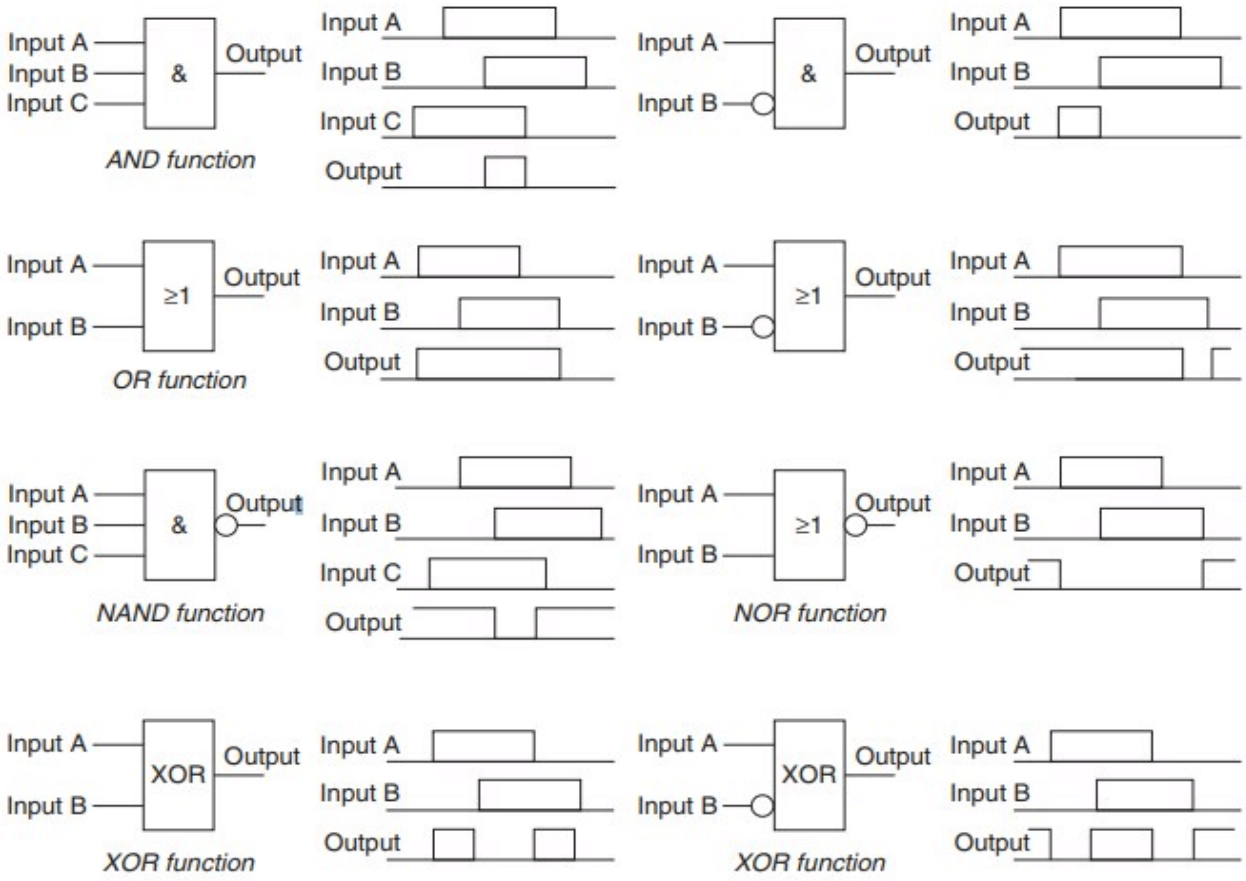


Figure 4.33.Functional Block Programming

The figure below shows a ladder diagram and its function block equivalent in Siemens notation.

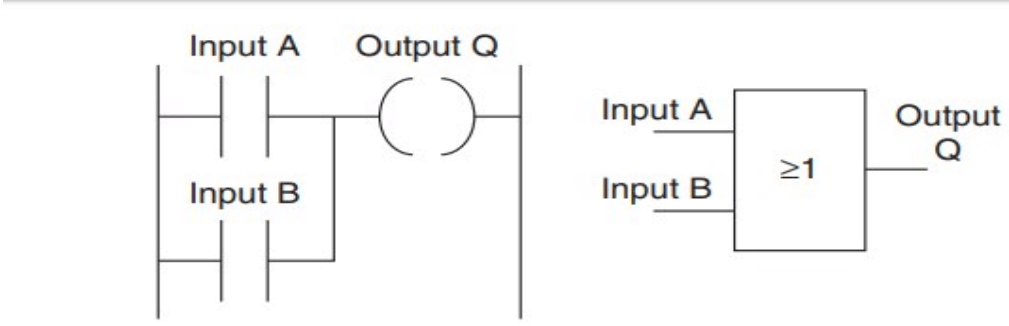


Figure 4.33 Ladder to functional block

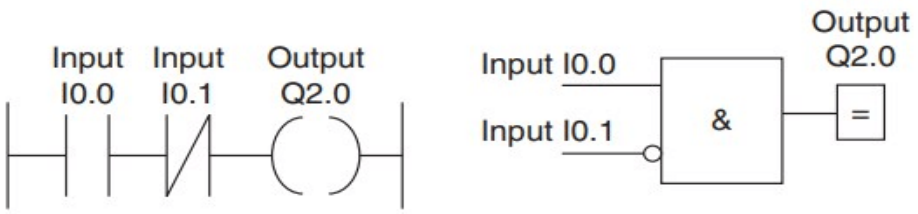


Figure 4.34.Ladder to functional block diagram

Structured Text Programming

Structured text is a textual programming language that utilizes statements to determine what to execute. It follows more conventional programming protocols but it is not case sensitive. A series of statements (logic) is constituted of expressing assignments and relationships using several operators. The structures text operators are listed below in the image.

Order	Operation
1.	( )
2.	function (…)
3.	**
4.	- (negate)
5.	NOT
6.	*, /, MOD
7.	+, - (subtract)
8.	<, <=, >, >=
9.	=, <>
10	&, AND
11.	XOR
12.	OR

Figure 4.35.Structured Text Programming

PLC Programming Examples

A signal lamp is required to be switched on if a pump is running and the pressure is satisfactory, or if the lamp test switch is closed. In this application, if there should be an output from the lamp inputs from both pump and pressure sensors are required. Hence, **AND logic gates** are used.

OR logic is used for the test input condition, it is required to give an output of lamp on regardless of whether there is a signal from the AND system. By using END or RET instruction in the ladder diagram, we can tell PLC has reached the end of the program. The function block diagram and the ladder diagram are shown below in the figure.

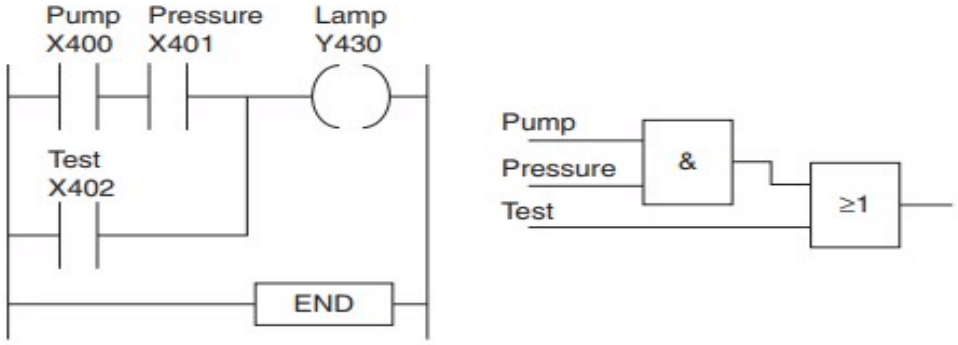


Figure 4.36.PLC Program to Test Lamp Glowing

As another example, consider a valve that is to be operated to lift a load when a pump is running and either the lift switch is operated or a switch operated indicating that the load has not already been lifted and is at the bottom of its lift channel.

OR logic is used for two switches and an AND logic is used with two switches and the pump. Valve will be operated only if the pump is ON and two switches are operated.

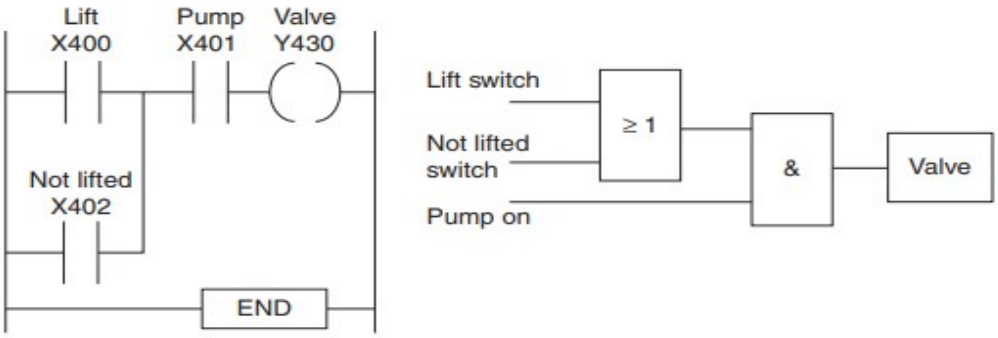


Figure 4.37.PLC Program to Operate Valve

Consider a drinks machine that allows the selection of tea or coffee, milk or no milk, sugar or no sugar, and will supply the required hot drink on the insertion of a coin. From the below-shown figure, it is seen that either tea or coffee is selected using the first OR logic gate.

The first AND gate give an output when either Tea or coffee is selected and a coin is inserted into the machine. The output from this AND gate is given to the second AND gate. The second AND gate operate only when hot water combines with tea. Milk and sugar are optional additions that can occur after a coin has been inserted.

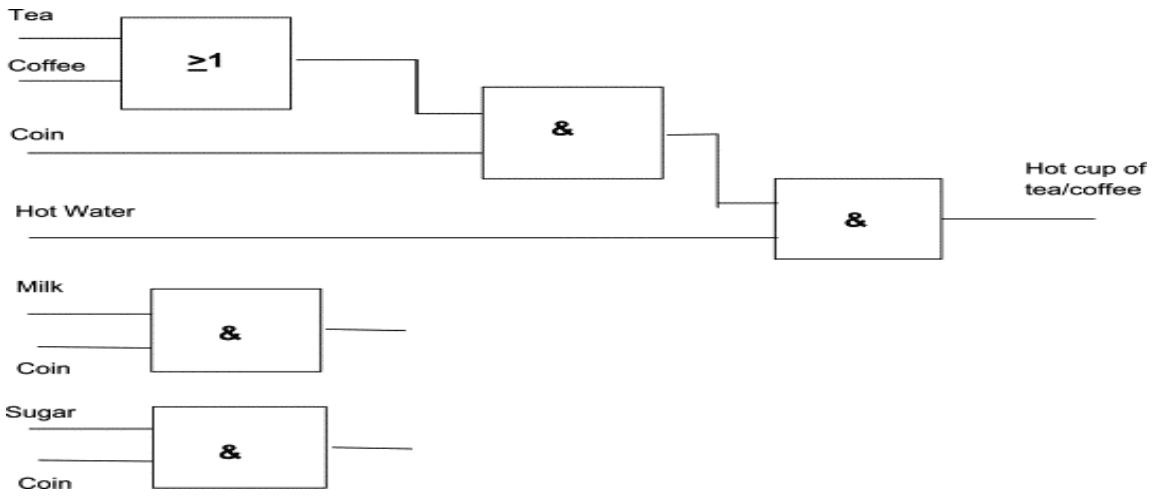


Figure 4.38.FBD for Drinking Machine

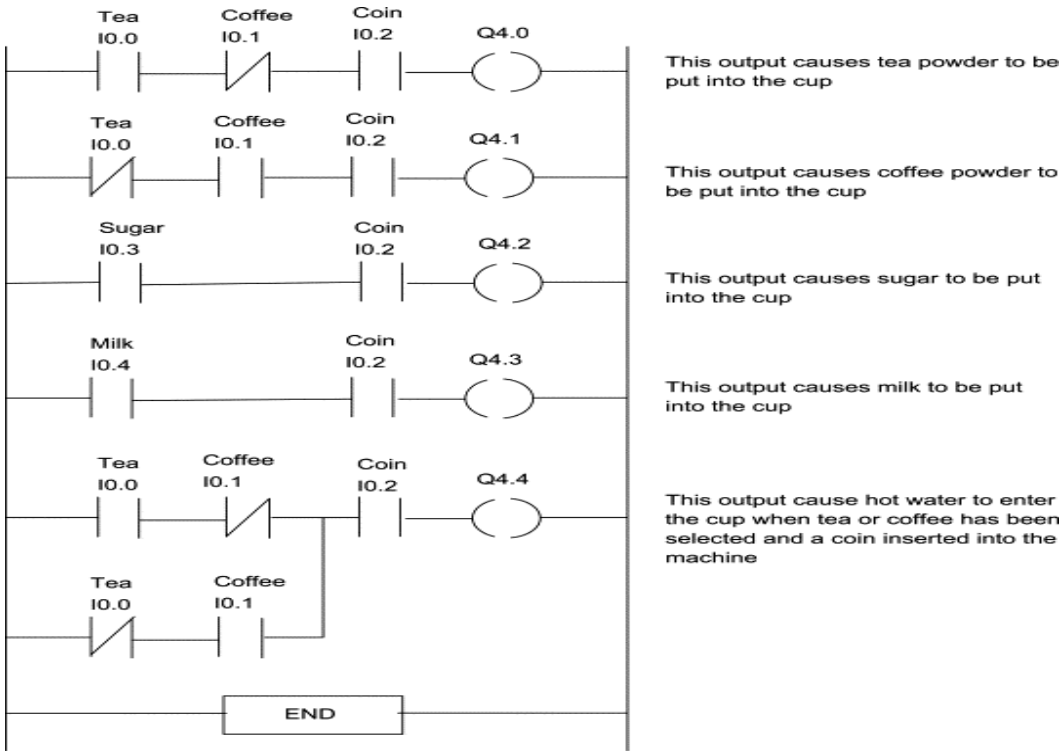


Figure 4.39. Ladder Logic for Drinking Machine Application

4.4.4.Concepts of I/O drivers the PLC system

A programmable logic controller consists of the following components:

HARDWARE

- Central Processing Unit (CPU)
- Memory
- Input modules
- Output modules and
- Power supply.

A PLC hardware block diagram is shown in Figure The programming terminal in the diagram is not a part of the PLC, but it is essential to have a terminal for programming or monitoring a PLC. In the diagram, the arrows between blocks indicate the information and power flowing directions.

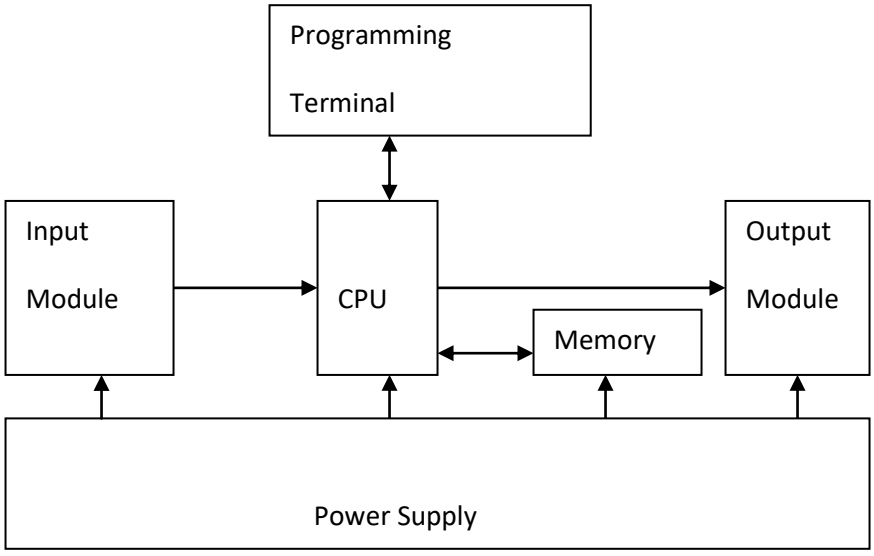


Figure4.40. PLC Hardware Block Diagram

Like other computerized devices, there is a Central Processing Unit (CPU) in a PLC. The CPU, which is the “brain” of a PLC, does the following operations:

Updating inputs and outputs. This function allows a PLC to read the status of its input terminals and energize or de-energize its output terminals.

Performing logic and arithmetic operations. A CPU conducts all the mathematic and logic operations involved in a PLC.

Communicating with memory. The PLC's programs and data are stored in memory. When a PLC is operating, its CPU may read or change the contents of memory locations.

Scanning application programs. An application program, which is called a ladder logic program, is a set of instructions written by a PLC programmer. The scanning function allows the PLC to execute the application program as specified by the programmer.

Communicating with a programming terminal. The CPU transfers program and data between itself and the programming terminal.

A PLC's CPU is controlled by operating system software. The operating system software is a group of supervisory programs that are loaded and stored permanently in the PLC's memory by the PLC manufacturer.

Memory

Memory is the component that stores information, programs, and data in a PLC. The process of putting new information into a memory location is called writing. The process of retrieving information from a memory location is called reading.

The common types of memory used in PLCs are Read Only Memory (ROM) and Random Access Memory (RAM). A ROM location can be read, but not written. ROM is used to store programs and data that should not be altered. For example, the PLC's operating programs are stored in ROM.

A RAM location can be read or written. This means the information stored in a RAM location can be retrieved and/or altered. Ladder logic programs are stored in RAM. When a new ladder logic program is loaded into a PLC's memory, the old program that was stored in the same locations is over-written and essentially erased.

The memory capacities of PLCs vary. Memory capacities are often expressed in terms of kilo-bytes (K). One byte is a group of 8 bits. One bit is a memory location that may store one binary number that has the value of either 1 or 0. (Binary numbers are addressed in Module 2). 1K memory means that there are 1024 bytes of RAM. 16K memory means there are 16 x 1024 =16384 bytes of RAM.

Input modules and output modules

A PLC is a control device. It takes information from inputs and makes decisions to energize or de-energize outputs. The decisions are made based on the statuses of inputs and outputs and the ladder logic program that is being executed. The INPUT MODULES accepts a variety of digital or analog signals from various field devices (sensors) and converts them into a logic signal that can be used by the CPU. The CPU makes decisions and executes control instructions based on program instructions in memory.

The input devices used with a PLC include pushbuttons, limit switches, relay contacts, photo sensors, proximity switches, temperature sensors, and the like. These input devices can be AC (alternating current) or DC (direct current). The input voltages can be high or low. The input signals can be digital or analog. Differing inputs require different input modules. An input module provides an interface between input devices and a PLC's CPU, which uses only a low DC voltage. The input module's function is to convert the input signals to DC voltages that are acceptable to the CPU. Standard discrete input modules include 24 V AC, 48 V AC, 120 V AC, 220 V AC, 24 V DC, 48 V DC, 120 V DC, 220 V DC, and transistor-transistor logic (TTL) level.

SENSORS

They are electronic devices that report to the PLC the status of the system to be controlled and if necessary, non-electrical signals are converted to electrical ones in order that they may be accepted by the input module. Sensor may include:

- Limit switches
- Cylinder switches
- Inductive sensors
- Capacitive sensors
- Reflective sensors
- Others

The OUTPUT MODULES convert control instructions from the CPU into a digital or analog signal that can be used to control various field devices (actuators). The devices controlled by a PLC include relays, alarms, solenoids, fans, lights, and motor starters. These devices may require different levels of AC or DC voltages. Since the signals processed in a PLC are low DC voltages, it is the function of the output module to convert PLC control signals to the voltages required by the controlled circuits or devices. Standard discrete output modules include 24 V AC, 48 V AC, 120 V AC, 220 V AC, 24 V DC, 48 V DC, 120 V DC, 220 V DC, and TTL level.

ACTUATORS

Actuators are the components that make devices move or start working. These actuators are:

- Motor Starters for Electrical Motors
- Solenoid Valves for Cylinders
- Encoder for Motor Controls

Power Supply

PLCs are powered by standard commercial AC power lines. However, many PLC components, such as the CPU and memory, utilize 5 volts or another level of DC power. The PLC power supply converts AC power into DC power to support those components of the PLC.

Programming Terminal

A PLC requires a programming terminal and programming software for operation. The programming terminal can be a dedicated terminal or a generic computer purchased anywhere. The programming terminal is used for programming the PLC and monitoring the PLC's operation. It may also download a ladder logic program (the sending of a program from the programming terminal to the PLC) or upload a ladder logic program (the sending of a program from the PLC to the programming terminal). The terminal uses programming software for programming and "talking" to a PLC. A PROGRAMMING DEVICE is used to input the desired instructions. These instructions determine what the PLC will do for a specific input.

SOFTWARE

It pertains to programs which specify the conditions under which the components in the installation are to be triggered. The software program, running on a PC, may be used to create a program for the PLC and is typically specific to one PLC or a family of PLCs. The common PLC programming languages are:

- Instruction List (IL)
- Structured Text (ST)
- Ladder Diagram (LD)
- Function Block Diagram (FBD)
- Sequential Function Chart (SFC)

4.5. Introductions of pneumatics and Electro-Pneumatics

4.5.1. PNEUMATICS

It is a branch of physics that deals with the study of gases especially air, its mechanical properties and applications at pressures higher (compressed) or lower (vacuum) than the atmospheric pressure. It comes from the Greek word "Pneuma" meaning breath.

It is the industrial implementation and application of air powered actuators (cylinders and motors) and their control devices (valves) needed in their operations.

Recall:

Pressure = Force / Area Newton / meter2 = Pascal Pneumatic pressures = 4 to 6 Bars (normal)

= 10 Bars (maximum) Force < 3 tons for Pneumatics

Force > 3 tons for Hydraulics

Conversions:

1 Bar ≈ 100 kPa = 14.5 psi

1 Atmospheric Pressure = 1.01325 Bar

= 14.7 psi

APPLICATIONS	Positioning
Transportation	Clamping
Feeder	Turning
Supply	Stamping
Positioning	Bending
Clamping	Hole boring
Transportation	Handling
Feeder	Assembly
Supply	Measuring
	Service life testing

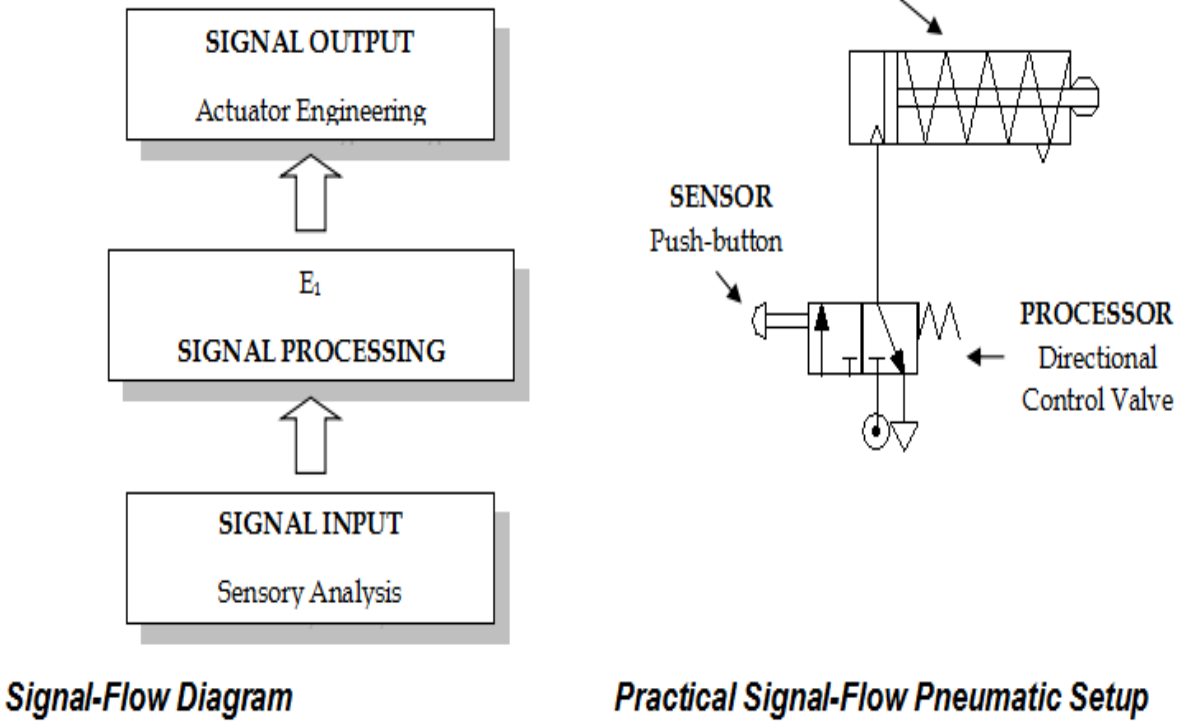
Top of Form

4.5.1.1 DESIGN AND STRUCTURE OF A PNEUMATIC CONTROL

Pneumatic controls are designed and represented in the form of control loops. The two basic forms of representation or basic functional groups for pneumatic controls are:

Signal-flow representation

Energy flow representation



Signal-Flow Diagram ***Practical Signal-Flow Pneumatic Setup***

Figure 4.41.signal flow

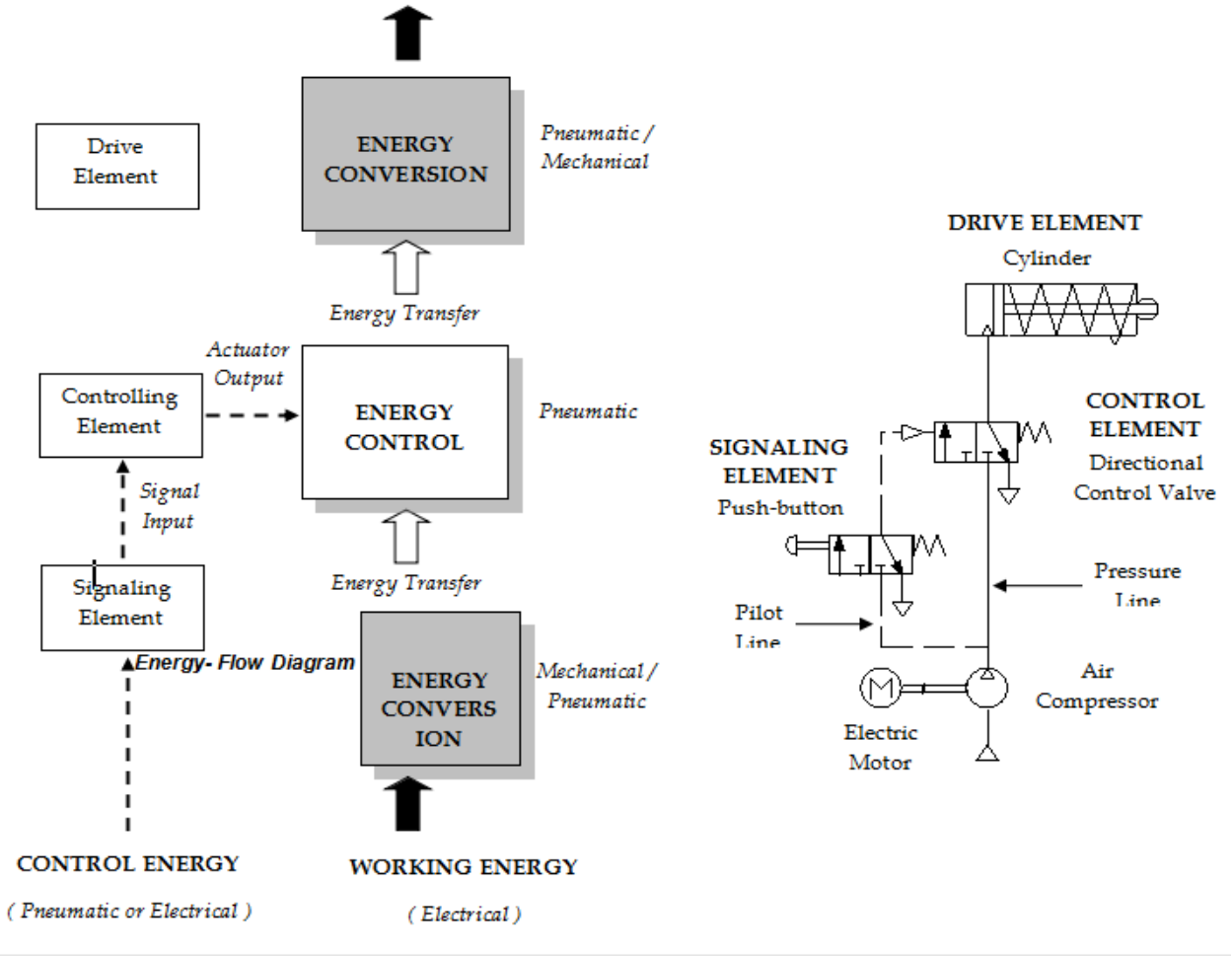


Figure 4.42. Practical Energy-Flow Pneumatic Setup

Compressed air is generated and conditioned in a central compressed-air unit and is then distributed in the installation through the compressed-air network.

PNEUMATIC POWER SUPPLY

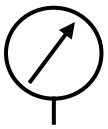
- Pneumatic systems are powered with compressed air. The source of compressed air is the central compressed-air unit also known as pneumatic power supply. The main devices included in the pneumatic power supply are:

- Compressor(s)
- Suction Filter
- Pressure switch
- Pressure relief valve

- Check Valve
- Cooler
- Filter with water trap
- Reservoir
- Pressure gauges
- Thermometers
- Hand-slide valve

PRESSURE GAUGE OF THE PRESSURE REGULATOR

A typical pressure regulator is normally fitted with a pressure gauge to indicate the operating pressure at the outlet port.

Pressure Gauge symbol 

DRIVE ELEMENTS

Pneumatic drive elements convert the energy in the compressed air into force and motion. The pneumatic drive elements can move in a linear, reciprocating or rotating motion.

SINGLE-ACTING CYLINDERS

The single-acting cylinder converts the compressed air energy into mechanical energy in the form of force and linear movement in one direction only.

The cylinder has two ports - a pressure inlet port and an exhaust port. The annular area (shaped like or forming a ring) of the cylinder is connected to the atmosphere

The compressed air is applied only on the bottom side of the piston that is why the cylinder can move loads or perform mechanical work in a forward motion only and that the effective force is reduced by the return spring. Single-acting cylinders are used in the assembling and packing automated lines to move, lift, feed, eject, press or push objects or to clamp parts. Practically, they are suitable for oil-free operation.

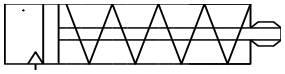


Figure 4.43.Single-Acting Cylinder, Spring Return

DOUBLE-ACTING CYLINDERS

The double-acting cylinder converts the compressed air energy into mechanical energy in the form of force and linear movement in both directions. This type of cylinder has two ports. The compressed air is applied at one of the working ports while the other working port is vented. They are used when the piston rod must perform work during its return stroke and when longer strokes are needed. When large loads are moved, double acting cylinders with adjustable stroke cushioning are to be used in order to avoid shocks at the cylinder bottom or cover. Such cylinders have two plungers (part of the device that thrusts or drops downward) on both sides of the piston. By means of two damping pistons and cap seals, an air cushion is formed which is then exhausted through the adjustable throttle.

The air which flows in quickly becomes effective due to the fact that the caps seals open up. Double acting cylinders are used for moving, pressing and lifting in pneumatic manipulators and automatic packaging machines.

Figure 4.44.Double-Acting Cylinder with Adjustable and Stroke Cushioning

ROTARY ACTUATORS

The rotary actuators transform the power of compressed air that generates linear piston movement into a reversible rotary movement. The piston rod of the actuator is designed in the form of a toothed rack with two pistons connected at each end. The linear motion created by introducing an air pressure to the piston/rack assembly is transmitted through a pinion (small gear wheel that engages with a larger gear or with a rack) to create a rotary motion. The rotation angle could reach and even overcome 360° depending on the cylinder stroke and on the gear ratio. The chamber between the two pistons is connected to the atmosphere, to avoid any trapped air from impeding any motion of the actuator. Available torque at the shaft is directly proportional to the difference in air pressure between the input and output ports.

Rotary actuators are used for turning details, bending pipes and bars, or for driving butterfly valves in pneumatic control systems.

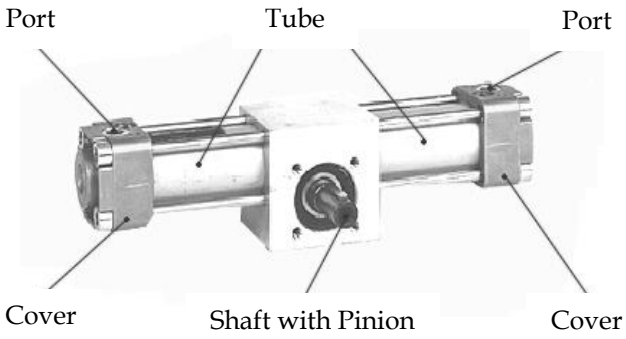


Figure 4.45.Typical picture of a Rotary Actuator

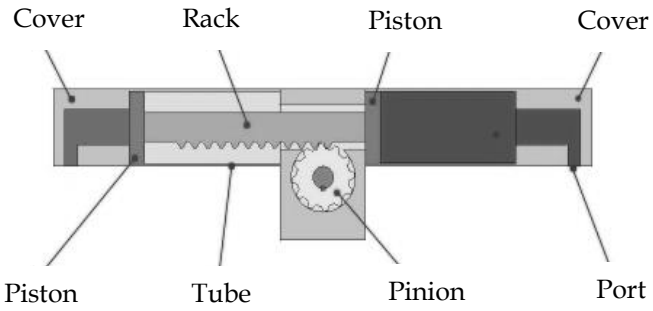


Figure 4.46.Cross-sectional view of the component's construction

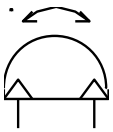


Figure 4.47. Rotary Actuator

Mode of Operation

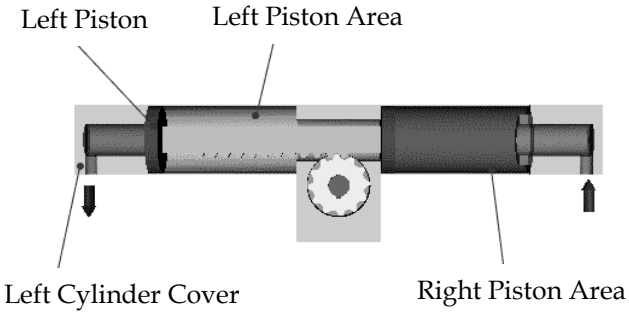


Figure 4.48. shows Mode of operation

When the left piston area is connected to the atmosphere and in the same time the right piston area is connected to the pressure line, the left piston is pressed to the left cylinder cover.

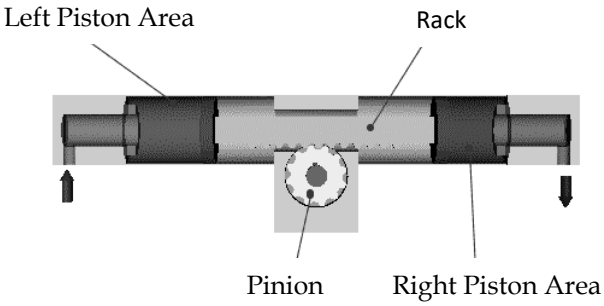


Figure 4.49. shows Mode of operation

Similarly, when the left piston area is connected to the pressure line and the right one is connected to the atmosphere the two pistons with the rack move to the right and the rack turns the pinion clockwise.

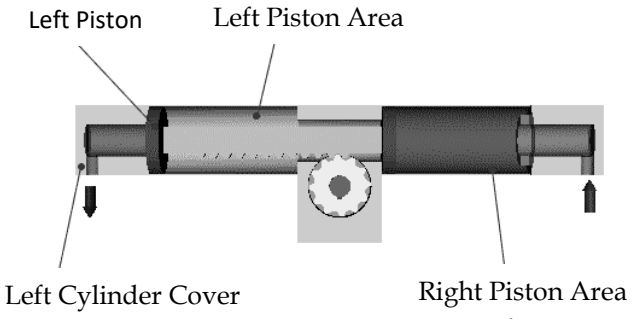


Figure 4.50.shows Mode of operation

Again, when the left piston area is connected to the atmosphere and the right one is connected to the pressure line the two pistons with the rack move to the left and the rack turns the pinion counter clockwise.

ACTUATORS, CONTROLLING ELEMENTS AND SIGNALING ELEMENTS

Valves are devices that controls the flow or movements of fluids like liquids or

gases through piping or other passages by opening or closing ports and channels.

DIRECTIONAL CONTROL VALVES

In pneumatic controls, directional control valves determine the flow of air between its ports by opening, closing or changing its internal connections. They are used as signaling elements, controlling elements and actuators to perform functions like:

- stopping the flow of compressed air
- controlling the through-flow of air
- controlling the direction of flow of air

CLASSIFICATION OF DIRECTIONAL CONTROL VALVES

- type of control
- type of the distributing element
- number of pneumatic connections or ports
- condition at neutral position whether normally closed and normally open valve

REPRESENTATION OF DIRECTIONAL CONTROL VALVES

Pneumatic elements are shown as standardized symbols as stipulated in DIN ISO 1219.

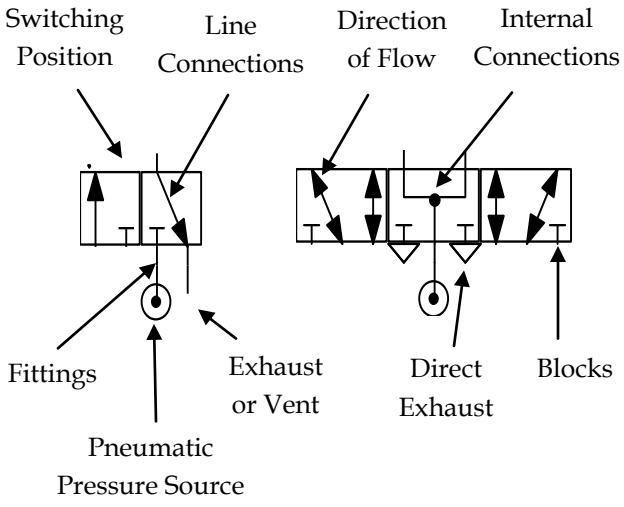


Figure 4.51. DIRECTIONAL CONTROL VALVES

Direct Exhausts are called open-air exit but it does not accept any connection to a distributor.

Exhausts are called restricted-air exit The exhaust acts as a pressure reducer and are inserted in the circuit wherever there is an exhaust port. It allows the evacuation of compressed air so that pressure will be null in all the parts of the circuit to which they are attached.

Switching positions and their respective control methods can be identified using lower case letters.

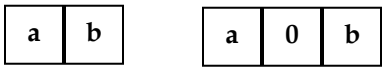


Figure 4.52. respective control methods

Normal Position of the valve is defined as the switching position assumed by the valve when it is not operated, say for instance due to the force of the spring.

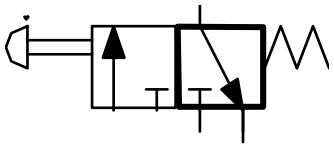


Figure 4.53.Normal Position

Initial Position of the valve is defined as the switching position assumed by the valve for instance to mechanical detent or due to the switching-in of supply energy.

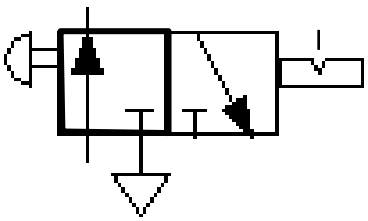


Figure 4.54.Initial Position

PORT OR CONNECTION DESIGNATION OF DIRECTIONAL CONTROL VALVES

PORT	DESIGNATION	
	LETTERS	ISO 5599
INPUTS (Supply)	A,B	1
OUTPUTS (Working Ports)		4,2
VENTS (Exhaust Ports)	R,S	
PILOT (Control Ports)		5,3
For 3/2 DCVs	Z,Y	12,10

3/2 MANUALLY OPERATED

DIRECTIONAL CONTROL VALVES

The 3/2 directional control valve (DCV), manually operated, is used to control the direction of the air flow in a single line of a pneumatic system. It connects the outlet port of the valve to its pressure inlet or exhaust port. 3/2 DCV allows manual or mechanical control of the pneumatic air flow in the circuit. They are used to provide input control of power signals given by an operator or by moving mechanisms of the system.

The 3/2 directional control valves are also used for the direct for the direct actuation of single-acting cylinders.

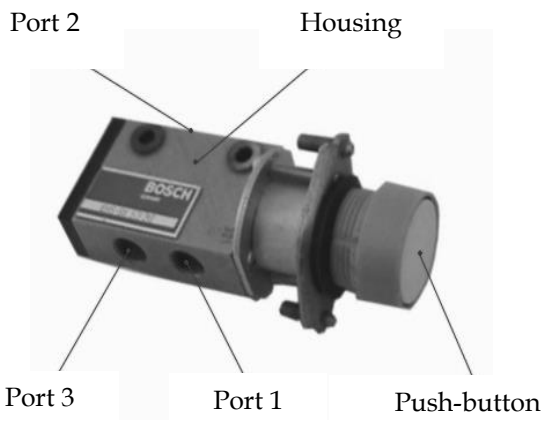


Figure 4.55Typical picture of a 3/2 way Normally Closed Directional Control Valve, Push-button Actuated, Spring Return

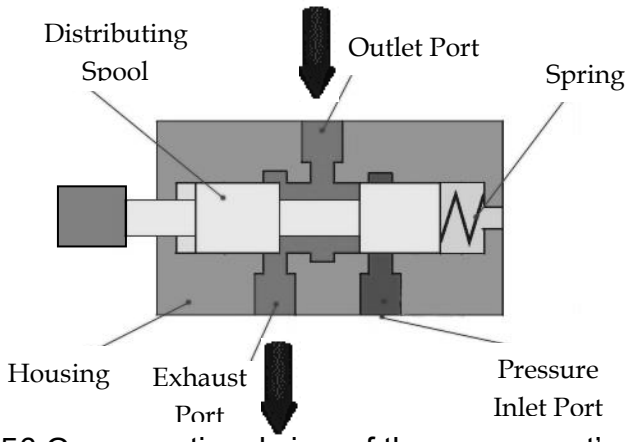


Figure 4.56.Cross-sectional view of the component's construction

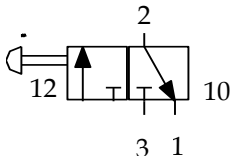


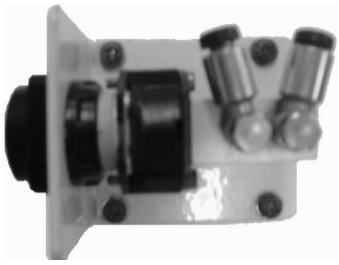
Figure 4.57.3/2 way Normally Closed Directional Control Valve,

Push-button Actuated, Spring Return

Typical picture of a 3/2 way Normally Open

Directional Control Valve, Push-button

Actuated, Spring Return



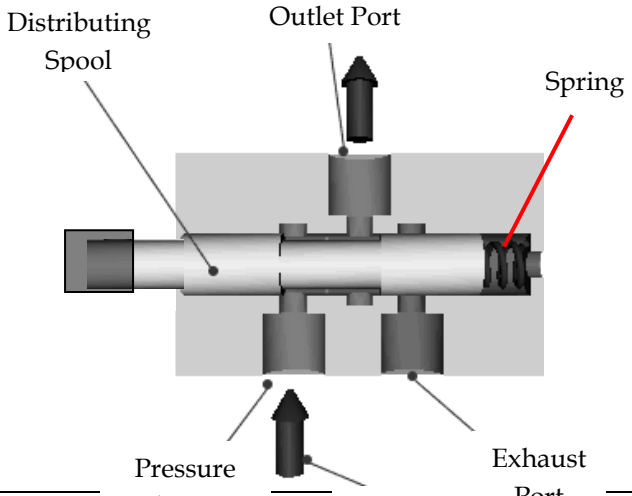


Figure 4.58.Cross-sectional view of the component's construction

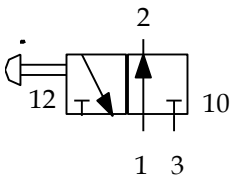


Figure 4.59.3/2 way Normally Open Directional Control Valve,Push-button Actuated, Spring Return

5/2 PNEUMATICALLY OPERATED DIRECTIONAL CONTROL VALVES

Basically, the 5/2 directional control valve functions the same as the 4/2 version. The only difference being that due to its design as a spool valve, the 5/2 has an additional exhaust port (5). In practically all applications, it is just as suitable as the 4/2 version but because of its outstanding features in terms of size, easy actuation and air passage being possible in both directions, the 5/2 is sometimes actually preferable to the 4/2 version.

The principles of operation of the pneumatically operated 5/2 directional control valve is dependent upon the movement of the spool inside the valve. The component shifts the connection between two outlet ports with a pressure inlet port and an exhaust port. By this means, pneumatic control of the system is achieved. In such valves, normally outlet ports are indicated as 2 and 4, pressure port 1, and exhaust ports 3 and 5.

The position of the valve spool is retained until a short pneumatic control signal is applied to any of the control ports. The 5/2 directional control valve, operated by pneumatic impulse, is applied in various practical solutions such as pushing off details, applying tools for performing operations, opening/closing doors and windows, stretch/bend robot/manipulator arms.

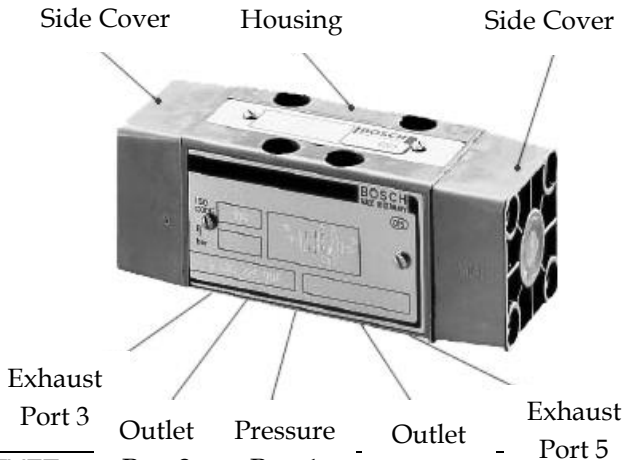


Figure 4.60.Typical picture of a 5/2 way Directional Control Valve, Pneumatically Actuated Both Ways

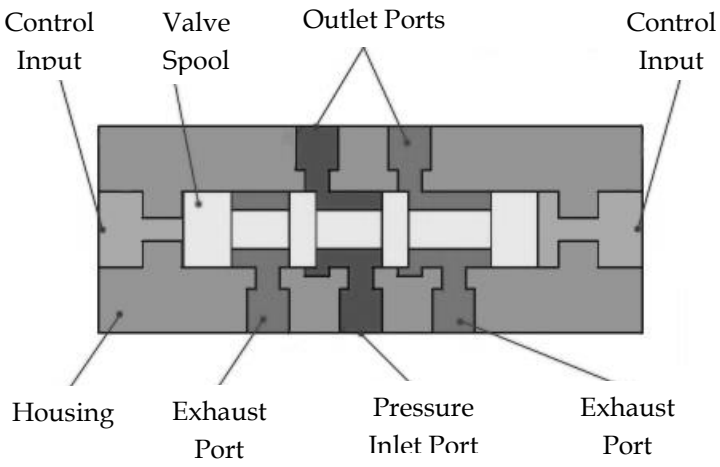


Figure 4.61.Cross-sectional view of the component's construction

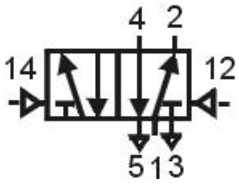


Figure 4.61 . 5/2 way Pneumatic Impulse Valve

Figure 4.63.Typical picture of another version a 5/2 way Pneumatic Impulse Valve

5/2 ELECTRICALLY OPERATED

DIRECTIONAL CONTROL VALVES

The principles of operation of the electrically operated 5/2 directional control valve is dependent upon the movement of the spool inside the valve. The component shifts the connection between two outlet ports with a pressure inlet port and an exhaust port using an electric control signal. By this means electric control of the pneumatic system is achieved. In such valves normally outlet ports are indicated as 2 and 4, pressure port 1, and exhaust ports 3 and 5. The position of the valve spool is retained until a subsequent electric control signal is applied to any of the control solenoids. The solenoid-controlled impulse valves are controlled by electrical pulses and are normally provided with pneumatic pilot control at both ends.

Usually, these valves are equipped with manual override at each end so that the valve can be switched even without electrical energy, say for instance during servicing and trouble-shooting. Electrically operated directional control valves are used in electro pneumatic systems included in material-handling systems, assembly process, opening and closing doors and windows; stretching and retracting robot arms.

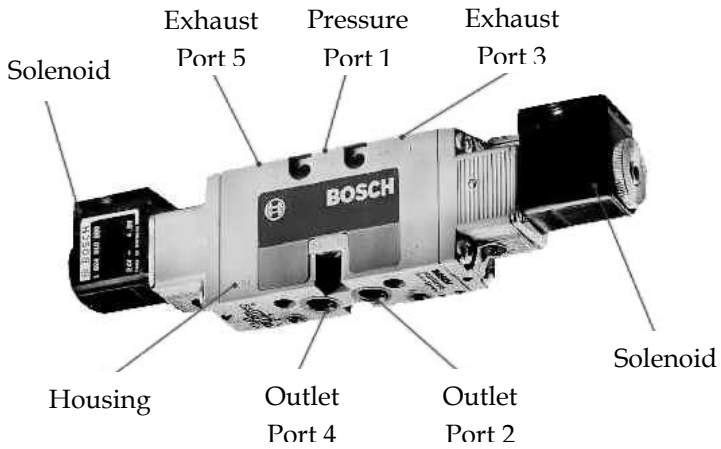


Figure 4.64. Typical picture of a 5/2 way Directional Control Valve, Electrically Actuated Both Ways

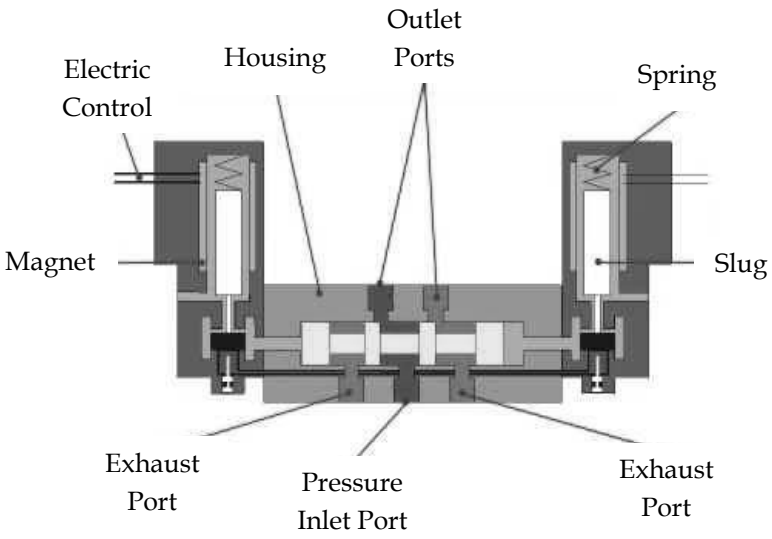


Figure 4.65.Cross-sectional view of the component's construction

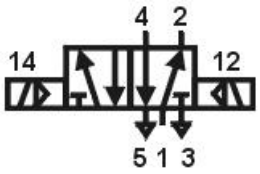


Figure 4.66. 5/2 way Solenoid-Controlled Impulse Valve

Figure 4.67.Typical picture of another version of a 5/2 way Solenoid-Controlled Impulse Valve

4.5.2. ELECTRO-PNEUMATICS

Electro-pneumatics is the industrial control technology that utilizes both pneumatic and electrical energy for generating straight line work motions, swiveling and reciprocating motions of pneumatically driven elements through a series of electrical switches and contacts.

Due to the ever-increasing demand on convenience during operation and the safety of control sequences, the number of signal and connection elements used has also been increasing. And due to the costs, these pneumatic signals and connection elements are increasingly replaced be electrical circuit elements such as electrical switches, sensors and relays.

4.5.2.1. DESIGN AND STRUCTURE OF AN ELECTRO-PNEUMATIC CONTROL

Electro-pneumatic controls are also designed and represented in the form of control loops. The two basic forms of representation or basic functional groups for electro-pneumatic controls ar

Signal-flow representation

Energy flow representation

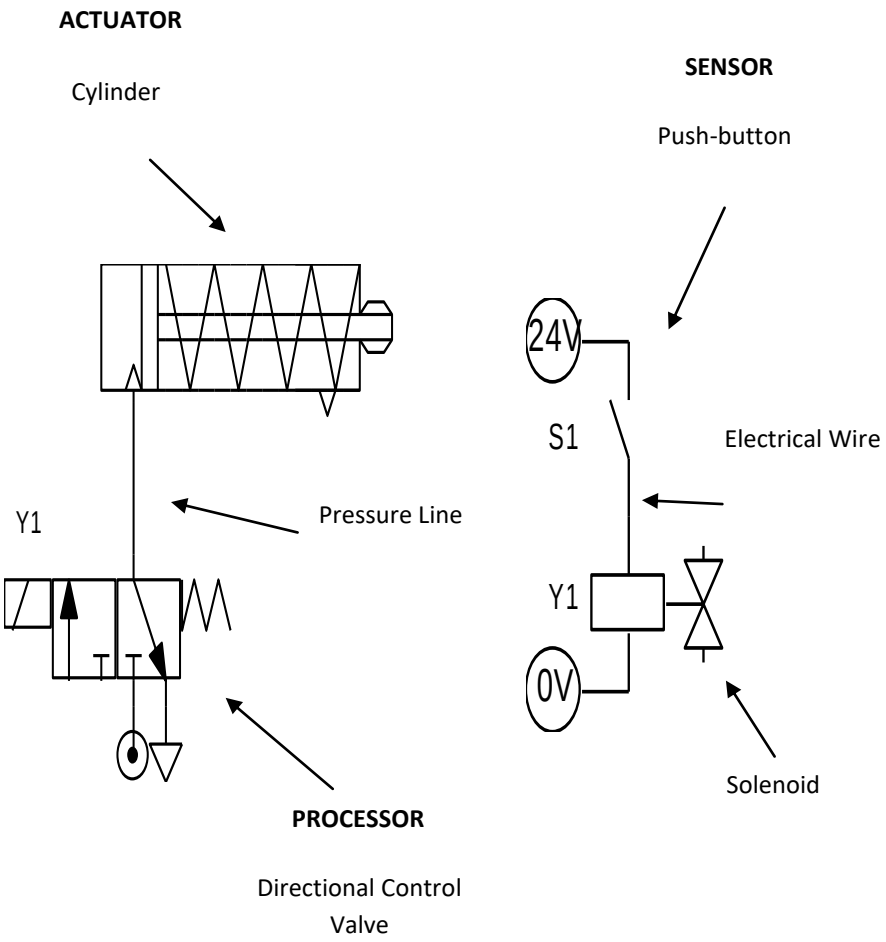
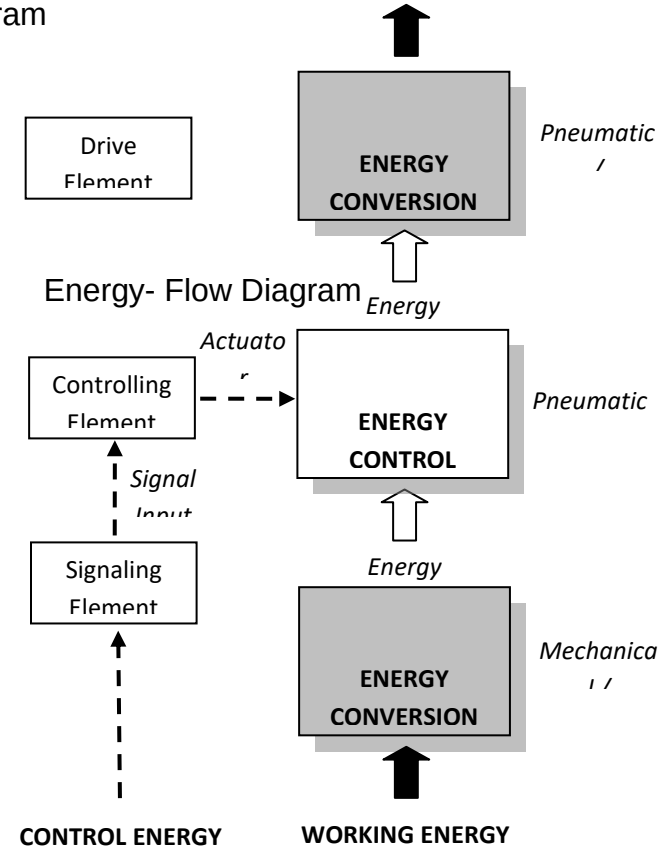
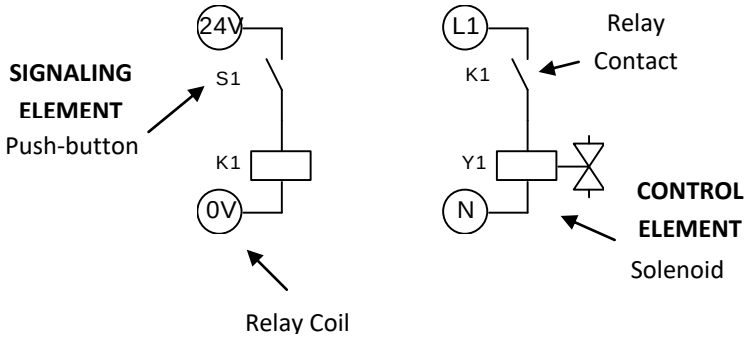


Figure 4.68.Practical Signal-Flow Electro-Pneumatic setup

Signal-Flow Diagram



Energy- Flow Diagram



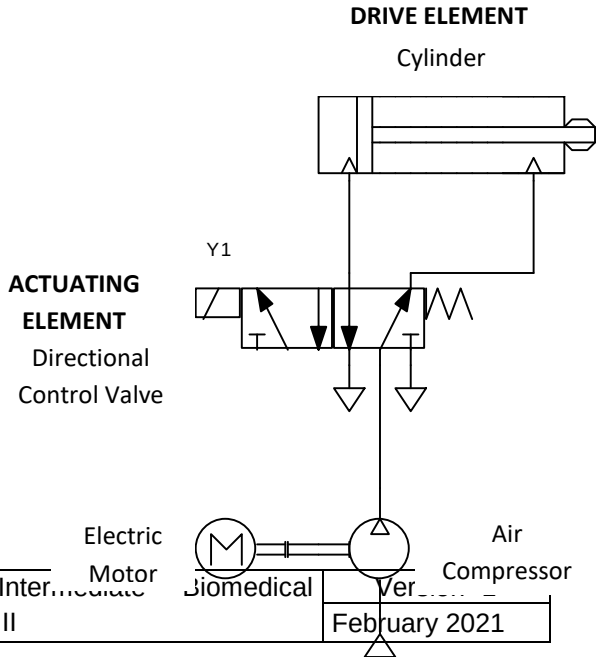


Figure 4.69.Practical Energy-Flow Electro-Pneumatic Setup

4.5.2.2. ELECTRO-PNEUMATIC CONTROL CHAIN

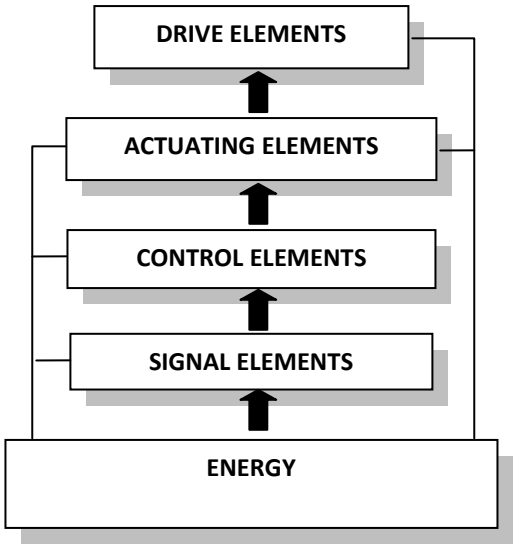


Figure 4.70.Electro-pnumatic control flow

ENERGY GROUP

Pneumatic and electrical energies are required in electro-pneumatic controls.

Signal elements, control elements and actuating elements are supplied with electrical energy.

Actuating elements and drive elements are supplied with pneumatic energy.

SIGNAL ELEMENTS

The signaling elements convert manual commands and mechanical motions into electrical signals.

CONTROL ELEMENTS

The control elements connect the approaching signals and direct these to the components of the actuating element group.

ACTUATING ELEMENTS

The actuating elements take over the function of connecting or converting electrical energy and pneumatic energy.

DRIVE ELEMENTS

The drive elements convert the pneumatic energy into mechanical energy and motions.

ELECTRICAL SWITCHES

These electric circuit elements are either manually or mechanically operated contacts that interrupts or closes the circuit. Electrical switches are designated by the capital letter S.

The three different types of contacts which represented with symbols following DIN

40713 are as follows:

Switch-On Element, Terminator

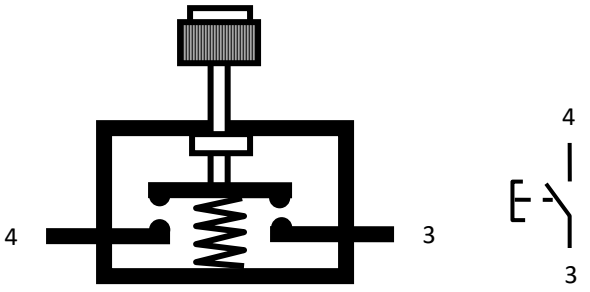


Figure 4.71.Switch-On Element, Terminator

Switch-Off Element, Opener

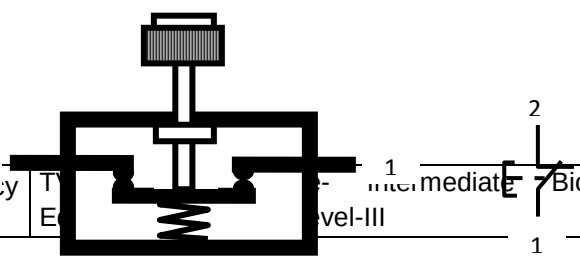


Figure 4.72. Switch-Off Element, Opener

Switch-Over Element, Alternator

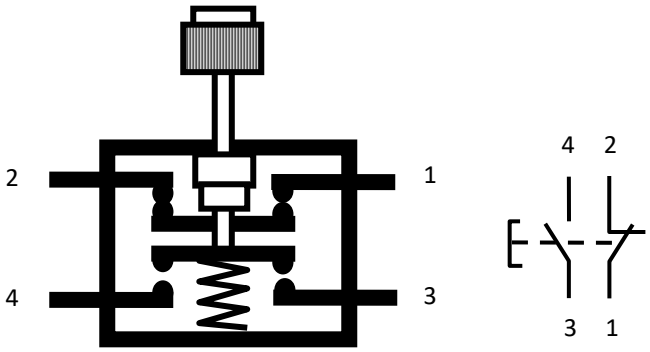


Figure 4.73. Switch-Over Element, Alternator

Switch elements are divided into two main types:

Key-operated Switch

It is an electric switching element which, after activation, returns to its home position automatically.

Actuating Switch

It is an electric switching element that retains its position even after activation has been stopped.

The actuating switch has to be unlocked by hand again

It is symbolized by a notch which is drawn between the operation symbols and the contact.

SOLENOID VALVES

Solenoids are electrical devices consisting of a cylindrical coil of wire surrounding a moveable iron core that moves along the length of the coil when an electric current is passed through it.

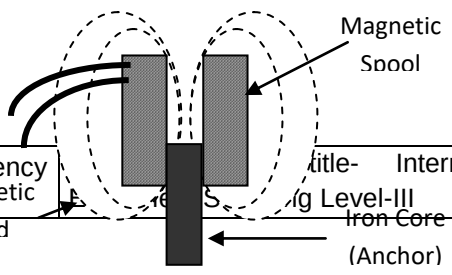
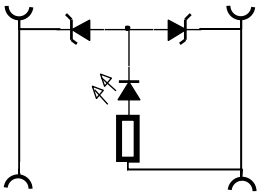


Figure 4.74. Magnetic Activation of Solenoids

For solenoid valves, if current is allowed to flow through a spool of wire that is wrapped around a magnetic spool body in various locations, a magnetic force field is generated in the inner empty space of the spool. The force field is able to pull an iron core (slug or slider) or a tappet made of ferrous material. This magnetic action of electricity on the magnetic spool is converted into force or mechanical motion which has a straight-line effect and is used in the switch-over of directional-control valves. For this magnetic action generated by the solenoid valves, they are also referred to as magnetic valves.

The common operating voltages for solenoid valves are 24, 42, 110 and 220 volts for AC or 24, 36 and 48 volts for DC. The power intake of magnetic spool lies between 2.5 to 12 watts in case of DC voltages and between 5 to 14 VA in case of AC voltages. Solenoid valves are designated by the capital letter Y.



Note that there are number of magnetic spools are designed for both types of voltage with the given symbol above.

3/2-WAY DIRECTLY-CONTROLLED SOLENOID VALVES

Directly-controlled solenoid valves can be used in small structural units and are normally fitted with a manual override or an auxiliary hand actuator. For larger structural design, it is necessary to use magnetic spools which have higher power. However, this results in greater heating of the magnetic spools and the magnets.

Figure 4.75.Typical picture of a Directly-Controlled3/2-way Solenoid Valve

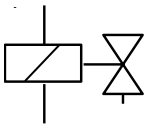


Figure 4.76. Solenoid Valve

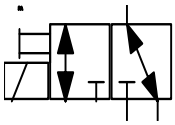


Figure 4.77.Directly-controlled 3 / 2-way Normally-Closed Solenoid Valve

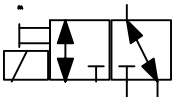


Figure 4.78.Directly-controlled 3 / 2-way Normally-Open Solenoid Valve

NOTE In electro-pneumatic controls, the 3/2 magnetic valve is the actuator for the control of single-acting cylinders.

3/2-WAY PRE-CONTROLLED SOLENOID VALVES

For large structural type applications, it is often necessary to apply valves with built-in pre-control or negative internal piloting.

Magnetic spools with lesser power can therefore be applied for a more reliable control of the valves and heating problems are not expected. Note that with pre-controlled valves, the minimum allowable pressure ranges from 0 to 3 bar depending on the structural design or nominal size of the connectors.

Figure 4.79.Typical picture of a Pre-Controlled 3/2-way Solenoid Valve

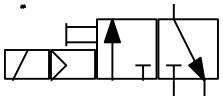


Figure 4.80.Pre-controlled 3 / 2-way Solenoid Valve

The plunger (anchor) is no longer connected directly connected with the main slider, rather it controls a relatively small seal element through the plunger. This seal element opens the passage in the control chamber of the slider when the magnets of the control air approaching from the switch canal are flowed through with current. The slider shifts the control and the valve activates. After the voltage drops, the magnetic force field in the spool collapses and the spring presses the anchor downwards and then the air supply in the control chamber is interrupted and ventilated.

RELAYS

Long before microprocessors, transistors, or even, vacuum tubes, there were relays. These electromechanical devices were in use long before World War II in a variety of applications as control and switching elements. Their only real drawback as compared to solid-state semiconductors is speed and current consumption. While a transistor can turn on and off millions of times per second a relay will only achieve operation cycles in the hundreds per second. And when a transistor is on, its power consumption is nothing (< 1 mA) compared to its load, a relay will typically draw an additional 50-100mA for the coil.

But they are quite simple and provide the safest isolation when supply voltages of the relays and the load have different levels of voltages or if the load voltage requirement is an AC voltage. Many of today's logic circuits have their roots in equivalent relay circuits.

Relays, which are also called as auxiliary contactors, are only able to control small powers. For higher power applications, contactors are utilized. The most spool nominal voltages are 6, 12, 24, 60 volts DC and 24, 100, 220, 240 volts AC. The circuit currents lie between 0.5 to 3 amperes and the circuit power lies between 10 to 500 watts.

Electro-mechanical relays are designated by the capital letter K.

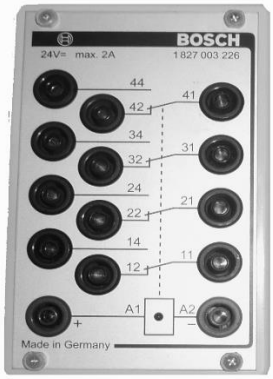


Figure 4.81. Typical picture of an Electro-Mechanical Relay

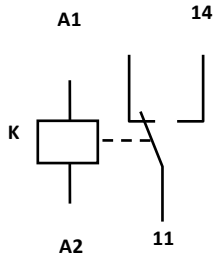


Figure 4.82.Electro-Mechanical Relay

A relay is composed of a magnetic spool with an iron core. It has an anchor that is fixed in the output position because of a return spring. The anchor is fitted with a movable isolated contact part. The other parts are the contact terminals and the coil terminals.

If a voltage is placed on the connectors of the spool (A1 and A2), the iron core becomes magnetic and it then pulls the anchor causing the contact is switched over. If the voltage on the spool is interrupted again, the magnetic force field breaks down again and it then releases the anchor to assume its original output position due to the return spring causing the contacts to switch-over again.

Note that there are special structural forms of relays that retain their actuated position even after the removal of the spool voltage, and these special relays are called current-impulse relays or remnant relays.

LIMIT SWITCHES

Limit switches are generally used to register the positions of pneumatic cylinders such that, depending on this action, a further action is triggered. The use of limit switches therefore applies to position-dependent controls. They are often mounted on the rear and forward end positions of the cylinder pistons and are activated directly by the piston rods.

Limit switches are grouped according to the contacting type (Mechanical limit switches) or the non-contacting type (Cylinder switches).

MECHANICAL LIMIT SWITCHES

The mechanical limit switches are contacting-type of limit switches and are normally referred to as roller limit switches.

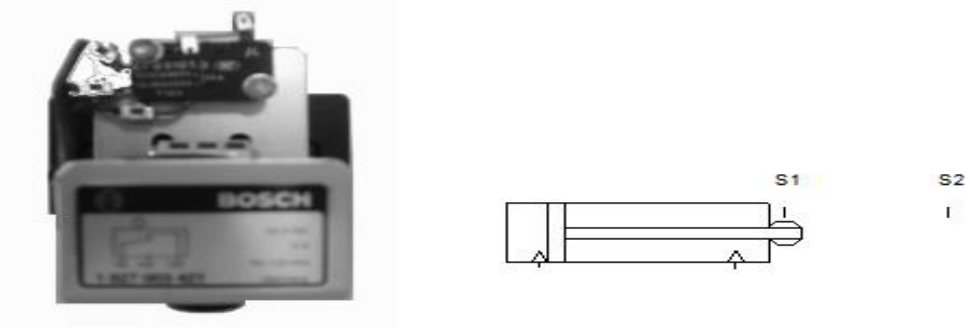


Figure 4.83.Roller Limit Switch

This signal element is designed as an alternator and can activate voltages of up to 220 volts. They are often built very small and referred to as micro-switches.

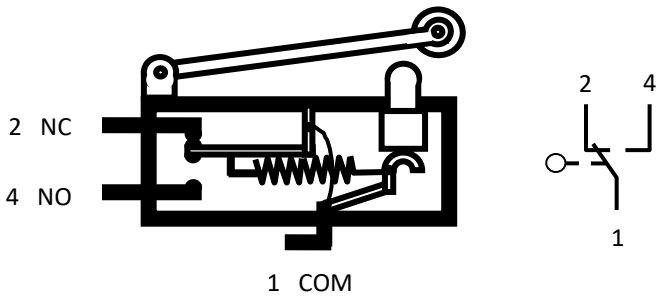


Figure 4.84.Typical picture of a Roller Limit Switch

The location of the assembly or the activation of the end switch is represented through a bar and labeled.

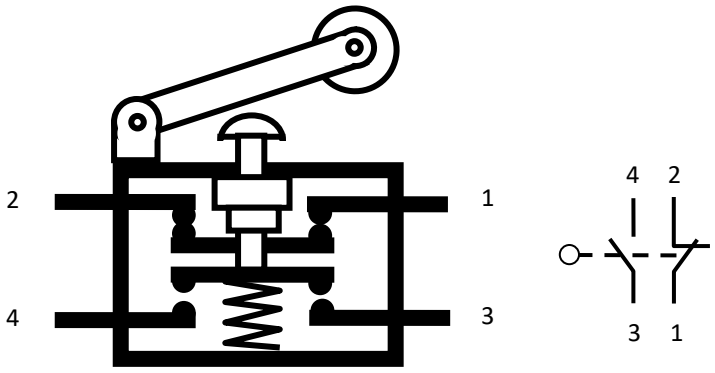


Figure 4.85.Roller Limit Switch

The bigger versions of the roller limit switches have a built in shutter contacts and an open-contact. These signaling elements can also activate voltages of up to 220 volts but at higher power ratings of up to 2 kW.

INITIALLY ACTUATED LIMIT SWITCHES

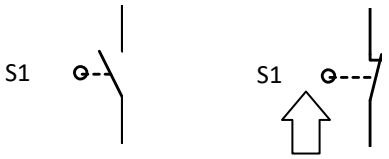


Figure 4.86.Shutter-Type Roller Limit Switch

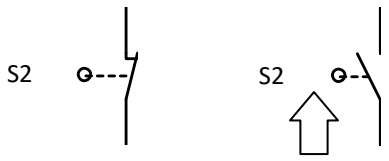


Figure 4.87.Opener-Type Roller Limit Switch

Note:- that an additional identifier in the form of an arrow represents the initially actuated condition of limit switches. Mechanical limit switches are designated by the capital letter S.

Self-Check 4	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 1 point)

1. An interconnection of elements and devices for a desired purpose.
A. System B. A control system C. Feedback D. Output

2. The input and output relationship represents the cause-and-effect relationship of the process.
A. A control system B. Process C. Feedback D. Output

3. Consists of subsystems and processes assembled for the purpose of obtaining a desired output with desired performance, given a specified input.
A. Manipulated Variable B. A control system C. Feedback D. Output

4. The actual response obtained from the system. It may or may not be equal to the specified response implied by the input.
A. Manipulated Variable B. Error C. Feedback D. Output

5. That portion of the output of a system that is returned to modify the input and thus serve as a performance monitor for the system.
A. Manipulated Variable B. Error C. Feedback D. Output

6. The difference between the input stimulus and the output response. Specifically, it is the difference between the input and the feedback.
A. Manipulated Variable B. Error C. Feedback D. Output

7. _____. is the quantity or condition that is measured and controlled. Normally controlled variable is the output of the control system.
A. Manipulated Variable B. Error C. Feedback D. Output

8. _____. is the quantity of the condition that is varied by the controller so as to affect the value of controlled variable.
A. Manipulated Variable B. Error C. Feedback D. Output

9.

10.

II Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is microprocessor?

_____

_____

2. The difference between combinational circuit and sequential circuit?

_____

_____

_____

3. **L**ist all the PLC hardware component?

_____

_____

_____

4. The two basic forms of representation pneumatic system?

_____

_____

_____

5. List Main types Switch elements?

_____

_____

. Answer the following question!

Note: Satisfactory rating 5 and 8 points Unsatisfactory below 5 and 8 points

You can ask you teacher for the copy of the correct answers.

Score = _____

Rating: _____

Answer Sheet

Name: _____ Date: _____

Short Answer Question

Operation title: -Read and interpret simple ladder logic diagram

	Operation sheet #1	TEVET QULIFICATION	IBMES Level III

Operation Title: Read and interpret simple ladder logic diagram

Purpose:

- To practice the skills in interpret PLC ladder logic diagram.

Conditions or Situation for the Operation:	Given the set of hand tools and equipment's • You will be provided with the working instructions • You will work on COMPUTER which have plc software. • You will finish your work in1hrs.

Equipment, Tools and Materials:

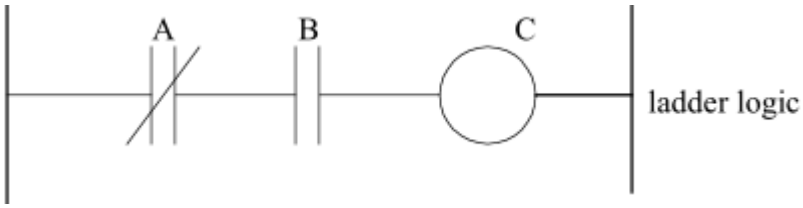
- computer, plc software

Procedure

Step 1. On your computer and check it have plc program.

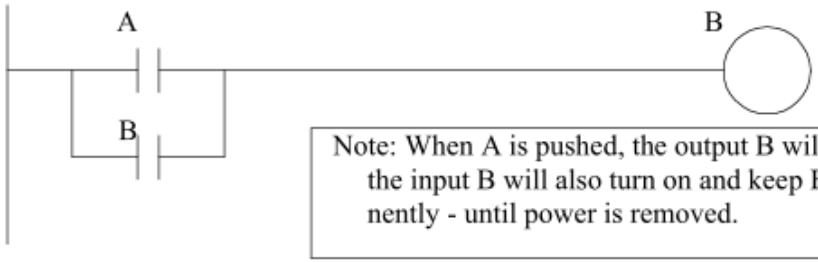
Step2. If it has, drawn instruction 1

Instruction:1



Step 3. Simulate the program.

Step 4. Analyze the operation.

	Instruction:2 : Follow the same procedure**.**  Note: When A is pushed, the output B will turn on, and the input B will also turn on and keep B on permanently - until power is removed. Note: The line on the right is being left off intentionally and is implied in these diagrams.
Precautions:	• DON'T FORGET you use ladder diagram
Quality Criteria:	• Work instructions are confirmed • Time management critical

Read and interpret simple ladder logic diagram

LAP Test 1	**Practical Demonstration**

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instructions:

1. You are required to perform any of the following:

   1.1. Read and interpret simple ladder logic diagram

   1.2. Prepare equipment and **material for** Read and interpret On your computer and check it have plc program

2. Request your teacher for evaluation and feedback

Operation title: -Read and interpret the diagram Pnumatic and electro pneumatic operation

	Operation sheet #2	**TEVET QULIFICATION**	**IBMS Level III**

Operation Title: Read and interpret the diagram

Purpose:

- To practice the skills in electro pneumatic operation .

Conditions or Situation for the Operation:	Given the set of hand tools and equipment's • You will be provided with the working instructions • You will work on electro pneumatic board. • You will finish your work in 3hrs.

Equipment, Tools and Materials:

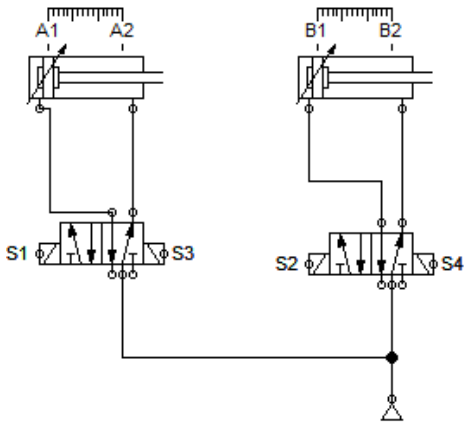
- electro pneumatic Board with all accessory .

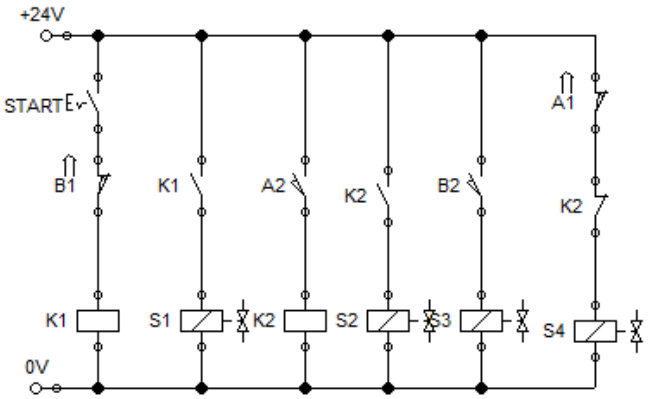
Procedure

Step 1. Read the diagram.

Step2. Select all necessary material and check its functionality.

Instruction: **A+B+A-B- electro-pneumatically**





	Step 3: connect the system according to the diagram. Step4: Before you give the power supply the trainer check your work. Sep5: After final check give supply and analyze the operation.
Precautions:	• DON'T FORGET follow safety rules.
Quality Criteria:	• Work instructions are confirmed • Time management critical

Read and interpret the diagram Pneumatic and electro pneumatic operation

LAP Test 1	Practical Demonstration

Name: _____ Date: _____

Time started: _____ Time finished: _____

Instructions:

1. You are required to perform any of the following:
   1.1. Read and interpret the diagram Pnumatic and electro-pneumatic operation
   1.2. Install and test pneumatics and Electro-Pneumatics control system
2. Request your teacher for evaluation and feedback

Information Sheet 5. Check BMECS for maintenance

5.1. Check BMECS for maintenance.

We will be expected to prepare for the instrumentation and control maintenance activities by obtaining all the necessary information, documentation, tools and equipment required, and to plan how you intend to carry out the required maintenance activities and the sequence of operations you intend to use.

You will be required to select the appropriate equipment to use, based on the maintenance operations to be carried out and the type of instrumentation and control equipment being maintained, such as pressure, flow, level and temperature instruments, fiscal monitoring equipment, fire and gas detection and alarm systems, industrial weighing systems, speed measurement and control systems, vibration monitoring equipment, nucleonic and radiation measurement, telemetry systems and emergency shutdown systems.

You will be expected to use a variety of maintenance diagnostic techniques and procedures, such as gathering information from fault reports, using recognized fault finding techniques and diagnostic aids, measuring, inspecting and operating the equipment. You will also be expected to cover a range of maintenance activities, such as isolating and locking off, disconnecting, removing and reconnecting instruments and faulty peripheral components, setting and adjusting components, and testing the equipment, using appropriate techniques and procedures.

Your responsibilities will require you to comply with health and safety requirements and organizational policy and procedures for the instrumentation maintenance activities undertaken. You will need to take account of any potential difficulties or problems that may arise with the maintenance activities, and to seek appropriate help and advice in determining and implementing a suitable solution. You will work under a high level of supervision, whilst taking responsibility for your own actions and for the quality and accuracy of the work that you carry out.

5.2, Specific Unit Requirements

In order to prove your ability to combine different process instrumentation and control maintenance operations, at least one of the instrumentation maintenance activities carried out must be of a significant nature, and must cover of the activities listed in below.

1) **Carry out all of the following during the instrumentation maintenance activities:**

- Adhere to procedures or systems in place for risk assessment, COSHH, personal protective equipment (PPE) and other relevant safety regulations
- where appropriate, ensure the safe isolation of instruments (such as electrical, pneumatic, process)
- follow job instructions, maintenance drawings and procedures
- check that the tools and test instruments are within calibration date and are in a safe and usable condition
- ensure that the equipment/system is kept free from foreign objects, dirt or other contamination
- return all tools and equipment to the correct location on completion of the maintenance activities

Carry out maintenance activities the following types of instrumentation and control systems are:

- pressure
- speed measurement
- fluid level
- noise

- fluid flow
- vibration monitoring
- temperature measurement
- nucleonic and radiation measurement
- fire detection
- telemetry systems
- gas detection
- weight measurement
- emergency shutdown
- alarm systems
- environmental
- other specific system

2) **Use the following maintenance diagnostic techniques, tools and aids: fault finding techniques (such as input/output, half-split, unit substitution)**
   - diagnostic aids (such as manuals, flow charts, troubleshooting guides, maintenance records)
   - information gathered from the person who reported the fault
   - visual checks (such as signs of damage, leaks, missing parts, wear/deterioration)
   - movement checks (such as loose fittings and connections)
   - monitoring equipment or gauges
   - test instrumentation measurement (such as voltage, resistance, current)
3) **Carry out all of the following instrumentation maintenance activities:**
   - removing excessive dirt and grime
   - replacing all `lifted' items (such as seals, gaskets)
   - taking electrostatic discharge (ESD) precautions (where appropriate)
   - replacing instruments/devices in the system
   - setting, aligning and adjusting components
   - disconnecting supply/signal connections
   - tightening fastenings to the required torque
   - removing instruments from the system
   - re-connecting instrumentation pipe work and power supply

- dismantling equipment to the required level
- labeling/marking of components
- checking signal transmission is satisfactory
- checking components for serviceability
- replacing or repairing damaged/defective components (such as electrical, mechanical and back-up batteries)
- functionally testing the maintained equipment

4) **Set up and test sensing elements and/or stand alone instruments, to include three of the following**:
   - pressure (such as bourdon tube gauge, capsule/diaphragm gauge, pressure transducers)
   - temperature (such as thermocouple, resistance thermometers, liquid in steel thermometer)
   - flow (such as differential pressure systems, balanced flow meters, positive displacement)
   - level (such as displacer systems, purged dip leg, capacitance probes, differential pressure systems, ultrasonic probes)
   - other instruments/sensing elements (such as fire or gas detection, noise or vibration, speed or weight)
   - Use the following types of instrumentation test and calibration equipment:
     - ✓ signal sources
     - ✓ pressure sources
     - ✓ logic probes
     - ✓ standard test gauges
     - ✓ comparators
     - ✓ temperature baths
     - ✓ analogue or digital meters
     - ✓ manometers
     - ✓ workshop potentiometers
     - ✓ digital pressure indicators
     - ✓ current injection devices
     - ✓ dead weight testers

- ✓ calibrated flow meters
- ✓ calibrated weights
- ✓ insulation testers
- ✓ special-purpose test equipment

5) **Maintain instrumentation and control systems, in accordance with one or more of** the following:

- organizational guidelines and codes of practice
- equipment manufacturer's operation range
- BS and ISO standards.

Self-Check 6	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. List carry out instrumentation maintenance activities (5%)

_____

_____

_____

_____

2. Describe maintenance diagnostic, tools aids and fault finding techniques (5%)

_____

_____

_____

_____

. Answer the following question!

Note: Satisfactory rating 5 and 8 points Unsatisfactory below 5 and 10 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____
Rating: _____

Name: _____ Date: _____

Short Answer Question

Information Sheet 6: Obtain necessary materials

6.1 Obtain tools, equipment and testing devices

Types of appropriate tools and test instrument

- **Tools**
  - ✓ **Pliers** are available with both insulated and uninsulated handles, which are used in handling and twisting wires. The handle insulation is not considered sufficient protection alone. Other safety precaution must be observed. Common types of pliers are:

***Figure 6. 1** different kind of pliers*

Screw drivers come in various sizes and shapes. They are used to drive and pull out screws. They are made of insulated handles with either sharp or square tips. The width of the screw driver should match the width of the screw slot.

Common types of screw.

Figure 6. 3 Different type of screw driver

Drilling Equipment is needed to make holes in building structure for passage of wires and conduit in both new and old installation, indoor or outdoor wiring. Common types of drilling tools and equipments are:

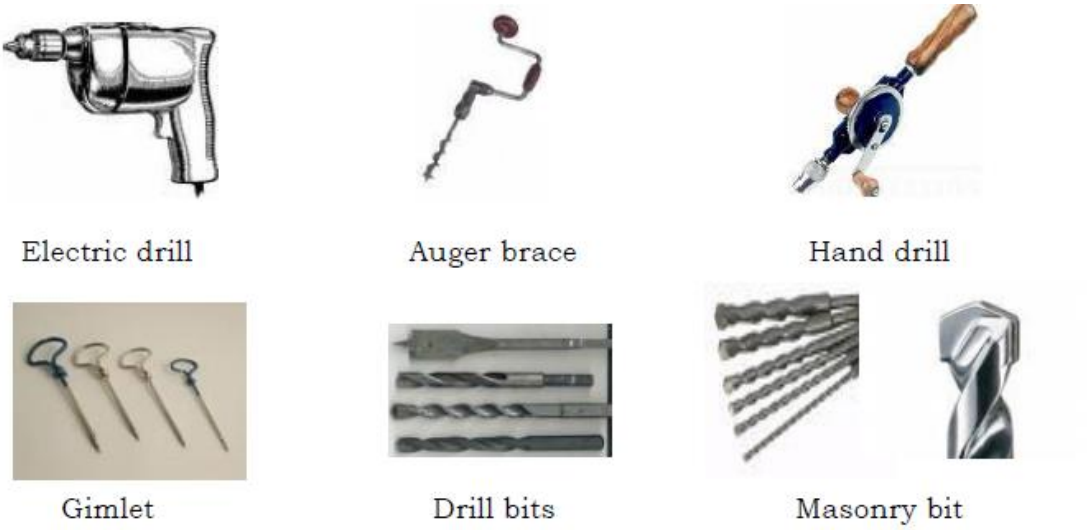


Figure 6. 4. Different type of Drilling Equipment

Hammers are used to drive and pull out nails. They are made of either hard steel or plastic. Common examples of hammer are:

Figure 6. 5.Different type of Hammers

Measuring tools and instrument:-

The electrician uses the following measuring tools and instruments to measure value of voltage, current and resistance, wire length, opening sizes of wire, conduit and other items.

Figure 6. 4.Different type of Measuring tools and instrument:

ECG book

is a document that summarizes the performance and other characteristics of a product, machine, component (e.g., an electronic component), material, a subsystem (e.g., a power supply) or software in sufficient detail that allows a buyer to understand what the product.

Self-Check -6	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Chose the correct answer

1. _____are used in handling and twisting wires.

   A. Pliers B. wrenches C. screw drivers D. hammers

2. Which of the following tool is used to make holes in building structure for passage of wires and conduit in both new and old installation, indoor or outdoor wiring

   A. Hammers B. wrenches C. drilling equipment D. soldering gun

3. _____ are used to drive and pull out nails.

   A. Pliers B. hammers C. wrenches D. screw drivers

4. _____ are used to drive and pull out screws.

   A. Pliers B. wrenches C. screw drivers D. hammers

5. Which of the following **is not** an example of instruments to measure electrical quantities

   A. Ammeter B. ohmmeter C. galvanometer D. pliers

Note: **Satisfactory rating - 3 and 5 point Unsatisfactory - below 3 and 5 points**

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

LG #24	LO #2- Maintain Biomedical Equipment Control Systems

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Performing periodic maintenance.
- Checking normal function of BMECS**.**
- Responding necessary adjustments appropriately
- Responding to unplanned events or conditions.
- Using appropriate **PPE**

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Perform periodic maintenance.
- Check normal function of BMECS**.**
- Respond necessary adjustments appropriately
- Respond to unplanned events or conditions.
- Use appropriate **PPE**

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,

9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet 1 : Performing periodic maintenance

1. Performing periodic maintenance

periodic maintenance: Periodic maintenance refers to activities performed on equipment based on a set time interval. The purpose of periodic maintenance, or time based maintenance, is to maintain smooth operation of a machine or other asset.

Periodic maintenance workflow

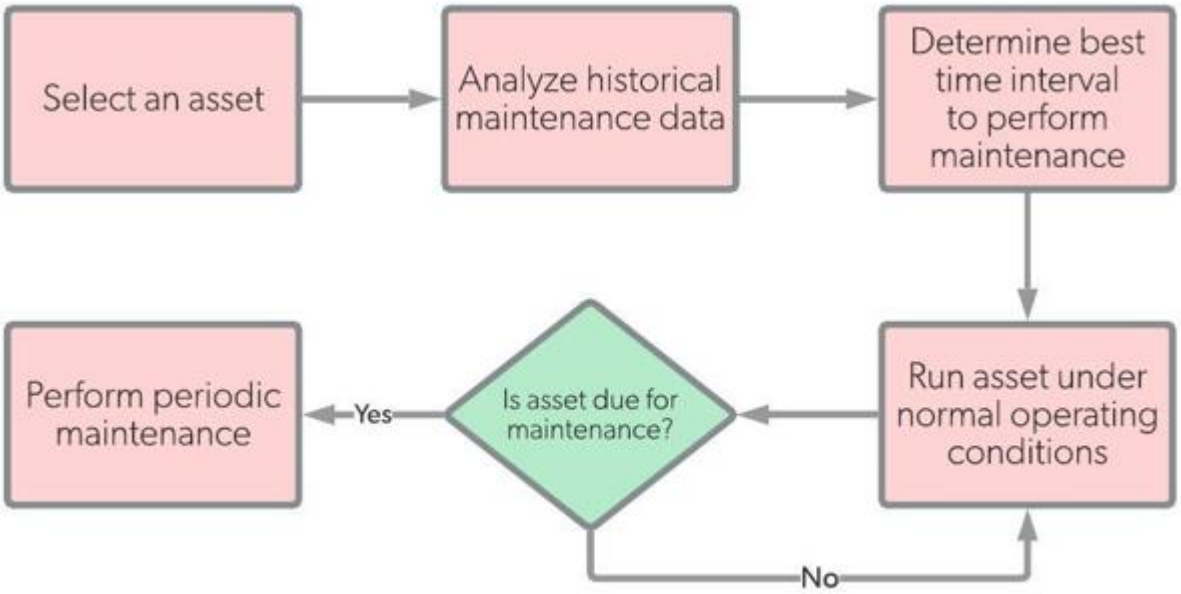


Figure 1.1. Periodic maintenance workflow

Wear and tear in equipment is unavoidable and assets would usually have a finite life span before eventually being retired from operations. The good news is, equipment doesn't just go end-of-life overnight. On the contrary, production assets are designed to be durable enough to last long periods. Within an equipment's life cycle, there is ample time to periodically check its condition to maximize its use.

Periodic maintenance, also known as time-based maintenance, is a strategy that requires maintenance tasks to be performed at set time intervals while the asset is operational. Similar to scheduled maintenance, periodic maintenance activities are planned ahead of time and are performed regardless of whether signs of deterioration are prevalent or not.

The identification of the interval and frequency of service tasks are evaluated depending on parameters specific to the asset. An equipment manufacturer might suggest calendar-based schedules to perform checks on your asset. For instance, an aircon manufacturer might recommend your window-type air conditioning unit to be cleaned out once a year as a general guideline.

Types of Medical Equipment Maintenance

Medical equipment brings along with it associated benefits and problems. The problem that draws the most attention is maintenance. Lack of a maintenance policy can result in no advance planning for maintenance budgets and thus no availability of spares and accessories. Many laboratories and health care programmes suffer because the installation and maintenance requirements are not planned in advance. This renders much equipment unusable and many devices lie idle because of lack of spares or funds.

Effective Maintenance Strategy

It is essential that we plan the resources required for maintenance. Planning will need to be made for both repair work and also for planned preventive maintenance. The following will also promote effective maintenance:

- User as well as service manuals
  - ✓ In procurement it should be made mandatory for the vendors to provide the following:
    - Training to technicians and operators.
    - Providing user / operating manuals.
    - Providing service / maintenance manuals
- Receipt and incoming inspection
  - ✓ Incoming equipment should be carefully checked for possible shipment damages; compliance with specifications in the purchase order; and delivery of accessories, spare parts and operating and service manuals.
- Inventory and documentation
  - ✓ A proper entry should be made in the inventory register. The inventory record should contain the serial number and date of receipt as well as date of completed inspection.

- Installation and final acceptance
  - ✓ Installation should be done by the vendor and training should be provided at this stage to the user as well as to the maintenance technicians.
- Equipment history record
  - ✓ There should be an equipment history record sheet to track the performance of the equipment. This sheet should note down the date of installation and commissioning, preventive as well as corrective maintenance records.

- Maintenance
  - ✓ Proper maintenance of medical equipment is essential to obtain sustained benefits and to preserve capital investment. Medical equipment must be maintained in working order and periodically calibrated for effectiveness and accuracy.
- Condemnation of old and obsolete equipment
  - ✓ The life cycle of medical equipment will vary from 5-10 years. If the equipment is declared obsolete by the vendor it may not be possible to get spare parts. Even if the parts area vailable it can become too expensive to obtain them and the equipment is no longer economical to repair. Condemnation of equipment should be well planned and the necessary steps should be taken in advance to arrange replacement.

Types and approaches to Maintenance of Medical Equipment:

There are two types of maintenance:

- Corrective Maintenance (or Repair)
  - ✓ This is done to take corrective action in the event of a breakdown of the equipment. The
    equipment is returned repaired and calibrated.
- Planned (or Scheduled) Preventive Maintenance
  - ✓ This work is done in a planned way before repair is required and the scheduled time for the work circulated well in advance. It involves cleaning, regular function / safety tests and makes sure that any problems are picked up while they are still small.

The choice of approach for Preventive and Corrective Maintenance depends on the complexity of equipment

- Maintenance by in-house trained technicians
  - ✓ The majority of the problems are relatively simple and can be corrected by a trained technician. Simple repairs and inspections are less costly when done this way. Vendors should provide training to in-house technicians at the time of installation and commissioning.
- Maintenance by manufacturer or third party
  - ✓ For specialized and advanced equipment, the vendor should provide maintenance services through a combination of on-call services and a maintenance contract negotiated at the time of the purchase. It will rarely be economical to provide this level of service in-house.

Levels of Maintenance

There are three levels of maintenance commonly identified:

- Level 1, User (or first-line)
  - ✓ The user or technician will clean the filters, check fuses, check power supplies etc. without opening the unit and without moving it away from the point of use.
- Level 2, Technician
  - ✓ It is recommended to call the local technician when first-line maintenance cannot rectify a faultor when a six monthly check is due.
- Level 3, Specialized
  - ✓ Equipment such as CT Scanners, MRIs etc. will need specialized engineers and technicians trained in this specific equipment. They are normally employed by third party or vendor companies.

As stated in the introduction, this manual is focussed on the User or First-Line Maintenance level. The reference section can be used to discover material for the other maintenance levels.

Planned Maintenance of Medical Equipment

Planned preventive maintenance is regular, repetitive work done at scheduled intervals to keep equipment in good working condition. The activities under preventive maintenance involve routine cleaning, calibrating and adjusting, checking for wear and tear and lubricating to optimize working efficiency and to avoid breakdown.

Also consumables replacement like the fitting of new of filters etc. is done as part of this work. Effective planning for preventive maintenance involves proper selection of the equipment to be included in the plan. Decisions must be made on what to include in order to reduce costs. Inexpensive units can be
replaced or repaired if they break down, so need not always be included. The overriding consideration is cost effectiveness.

Setting up a complete system

When many items of equipment are under the care of a single biomedical department, it is better to keep the planned preventive maintenance computerized with a programmed schedule. This will require:

- An equipment inventory
    - ✓ All equipment in the hospital should be recorded on cards or in the computerized database. All relevant information about the equipment must be entered, including its location, records of repair and maintenance and manufacturer details. A reference number is written on each item.
- Definition of maintenance tasks
    - ✓ These tasks can normally be established by consulting the manufacturer's literature
- Establishing intervals of maintenance
    - ✓ The frequency of these tasks must be decided. A heavily used item must be cleaned and checked more frequently than one which is used less often; however, minimum standards must be set. The frequency suggested in the

manufacturer's manual can be used as a guide, but the amount of actual usage should determine the maintenance procedure required.

- Personnel
  - ✓ The biomedical team will normally monitor the Preventive Maintenance Program.
- Reminder system
  - ✓ It will be necessary to develop a reminder system, so that staff are prompted to carry out tasks

    when they are due. A card index / calendar system or a computer program can be used.
- Special test equipment
  - ✓ A biomedical team should have a range of test equipment to check the correct functioning of

    equipment and its compliance with electrical and other safety standards.
- Technical library
  - ✓ A full technical library should be available.
- Surveillance
  - ✓ After the program has been set up, periodic surveillance must be carried out to ensure that

    records are legible and that all entries are being made.

2. Planning User Maintenance Tasks

The tasks outlined in this information sheet 1 are designed for the equipment user to carry out at the point of equipment use. No special equipment will be needed for these tasks, neither will a computer program be necessary.

The tasks are separated into Daily and Weekly tables in order to help users plan a routine of inspections. See table below How to use this manual for guidelines.

User Maintenance Checklist Anaesthesia Machines

Table 1.1. Maintenance Check List of Anaesthesia machine

Daily	
Cleaning	★ Remove any dust / dirt with damp cloth and dry off ★ Remove water and waste matter from inside
Visual checks	★ Check all screws, connectors and parts are tightly fitted ★ Check all moving parts move freely, all holes are unblocked
Function checks	★ Use troubleshooting guide if problems occur

Weekly	
Cleaning	★ Unplug, clean inside and outside with damp cloth and dry off
Visual checks	★ Check internal heating element connections are tight ★ Replace heating element if covered with limescale ★ If plug, cable or socket are damaged, replace
Function checks	★ When next used, check pressure / temperature gauges rise ★ When next used, check there are no leaks

Every six months
Biomedical Technician check required

Self-Check 1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1._____ refers to activities performed on equipment based on a set time interval.

A. Planning C. Commissioning

B Periodic maintenance D. All

2. A type of Maintenance is done to take corrective action in the event of a breakdown of the equipment

A. Preventing C. Commissioning

B. inventory D. Corrective

3. One incorrect about Setting up a complete system

A. An equipment inventory C. Definition of maintenance tasks

B. Establishing intervals of maintenance D. Equipment history record

. Answer the following question!

Note: Satisfactory rating 8 and 15 points Unsatisfactory below 3 and 6 points

You can ask you teacher for the copy of the correct answers.

Score = _____

Rating: _____

Answer Sheet

Name: _____ Date: _____

Information Sheet 2 Check normal function of BMECS

2.1 Check normal function of BMECS

System

A system is a combination of a functional unit that acts together in such a manner as to achieve the desired objective.

The term "System" is used to name a machine, set of rules or any collection of entities that produces an output signal in response to input signals.

This broad definition allows anything to be considered as System.The above figure shows that the Block diagram of a representation of the system. It produces an output corresponding to a given input signal in accordance with some rule. There can be any number of input and output signals.

A system can be Electrical, Mechanical, Hydraulic, pneumatic, Chemical, Analog and digital or combination.

It comprises the following:

- The material in solid, liquid or gaseous state.
- The flow of material.
- Interaction between material leading to physical and chemical changes and reactions.
- Process variable such as temperature, pressure, Humidity, Speed so on.

All these dynamic variables together with the dynamic changes taking place in the system constitute a process. Whenever these dynamic variables are controlled manually or automatically, we term as process control.

Automation has made the control of a process simpler, more precise, faster and more reliable.

Examples:

Air Conditioner: Temperature and humidity are inputs and controlled air is an output.

Doorbell: The press of a button is input and the Sound is output.

Measurement Systems:

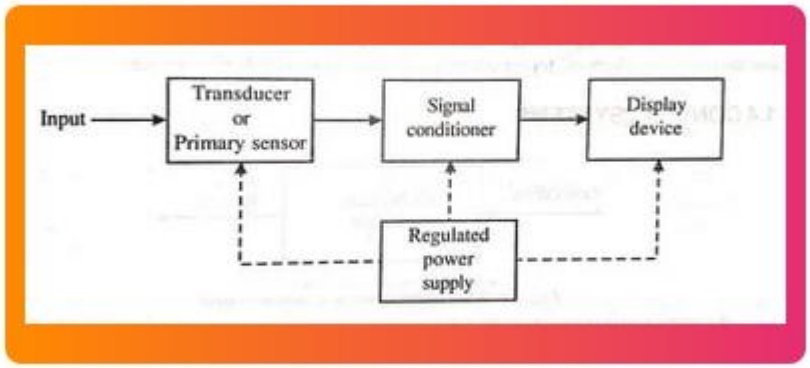


Figure 2.1.Measurement Systems

The above figure shows the block diagram of the electronic measuring system. It consists of the following four functional units:

1. Transducer or Primary Sensor
2. Signal Conditioner
3. Display device
4. Regulated power supply

Transducer or Primary Sensor:

The transducer or primary sensor sens the quantity under measurement and change it to a proportionate electrical signal. The input quantity in most of the instrumentation system is non-electrical (such as mechanical, chemical, optical, thermal, etc). This input quantity ultimately converted into an electrical signal because the electrical signal can easily be amplified, attenuated, filtered, detected, analyzed, modulated, transmitted, recorded and so on.

Signal Conditioner:

The signal conditioner converts the transducer output into an electrical quantity suitable for control, recording, and display. It is here that the signal is amplified, filtered or otherwise modified acceptable to the display device.

Display device:

The readout or display device may be a simple indicating meter, an oscilloscope or a chart recorder.

The information about the measurement is displayed in analog or digital format. Analog signals converted into digital form for automatic analysis, recording or process control.

Conversion of analog signals into digital format is done through the analog to digital converter (ADC).

Regulated power supply:

The electronically regulated power supply provides the required excitation to the transducer and the necessary electrical power to the signal conditioner and display device.

Control System:

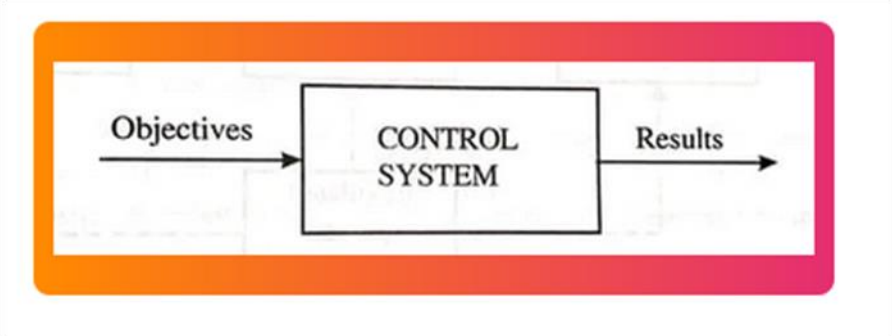


Figure 2.2.control system

A control system consists of the following three components.

1. Objective of control
2. Control system control
3. Result or Output

The relationship between these three components is shown in the above figure. The objective can be identified with inputs or actuating signals. The result also called output or controlled variables. The goal of the control system is to control the output in some prescribed manner by the inputs through the elements of the control system.

Application:

- Locomotives
- Robotics
- Material handling
- Biomedical, Surgical and endoscopic
- Aeronautics
- Marine
- Defense

- Space industries
- Smart transportation system on systems such as drive by wire system and driver-assist system.
- Steering control of an automobile
- Idle-speed of an automobile
- Sun tracking control of solar collectors.

What is control loop?

A Control loop is the fundamental building block of the industrial control system or industrial automation. It is a group of components working together as a system to achieve and maintain the desired value of a system variable by manipulating the value of another variable in the control loop.

An instrumentation control loop consists of a controller that can adjust the process variable equal to set point by measuring the current process variable using sensors.

Control System Types:

- Open Loop control System
- Closed Loop Control System

Open Loop control System:

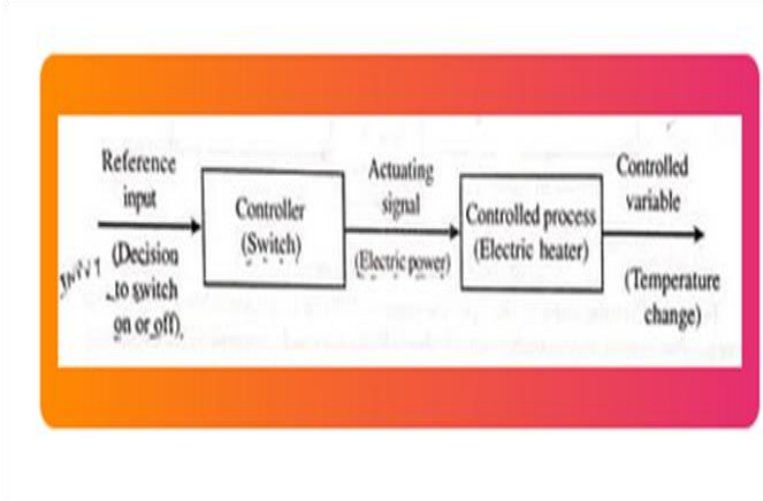


Figure 2.3: Open-Loop control system

An open-loop control system is one in which the control action is independent of the output. As the above figure has shown the elements of an open-loop control system can be divided into the following two parts:

- Controller and
- Controlled process

A reference input signal is applied to the controller, whose output access actuating the signal. The actuating signal then controls the control process so that the control variable will perform according to some prescribed standards.

Consider an electric room heater operated by a switch. If a person turns on the switch, the room will heat up and reach the temperature which is only determined by the wattage rating electric heater. The heat output cannot be adjusted and constant if there are changed in weather condition because no information is fed back to the heating element.

Example:

The conventional electric washing machine is an example of an open-loop control system because the wash time is set by the estimation of the human operator, but not on the basis of whether the clothes are clean properly. No information is fed back cleanliness off the clothes.

Advantages / Merits:

- The input command is the sole factor responsible for providing the control system.
- It is an ability to perform accurately is determined by its calibration.
- It is easier to build.
- It is not troubled with the problem of instability.

Disadvantages / De-merits:

- Presence of non-linearities causes malfunctioning.

Closed Loop Control System:

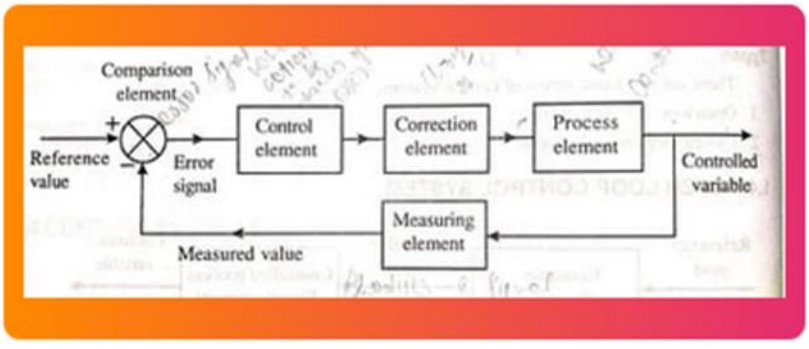


Figure2.4: Close-Loop control system

Feedback from the output to the input is missing in the open-loop control system. To obtain More accurate Control, the controlled variable should be fed back and compared with the reference input. An Actuating signal proportional to the difference of the input and output is used to correct the error. A System with one or more feedback path is called a closed-loop system.

A closed-loop control system is shown in the above figure.

It consists of the following five elements.

1**. Comparison element:** Comparison element gives the difference between the reference Input and feedback signal Error signal= (Reference value signal-Measured value signal)

2. Control element: Control element decides what action to take(for example, switch on or off when it receives an error signal)

3. Correction element: The correction element produces a change in the process to correct or change the controlled condition. Thus it might be a switch which switches on a heater and so increase the temperature of the process or a valve which opens and allow more liquid to enter the process. The term actuator is for the element of a correction unit that provides the power to carry out the control action.

4. Process element: The process being controlled could be a room in a house with its temperature being control or a tank of the water with its level being controlled.

5. Measuring element: The measuring element produces a signal related to the control variable(output). For example, it might be a Thermocouple which gives and EMF proportional to the output temperature.

Advantages / Merits:

- High accuracy

Disadvantages / De-merits:

- Complicated and costly.
- The system has a tendency to oscillate.

2.5.1. Components of a Control loop:

There are different types of control loop components combined work for the common desire of the system or to attain the set point. They are:

- Primary element/sensor
- Transducer
- Converter
- Transmitter
- Signal
- Indicator
- Recorder
- Controller
- Correcting element/final control element
- Actuator

Primary element/Sensors:

Sensors are the first element in the control loop which measures the change in the process and reporting the process variable so they are also called as the primary element. Sensors are devices which cause change when affected by a change in the process variable.

There are different types of sensors for measuring variables like Pressure,

- Temperature,
- Flow,
- Level,
- pH,
- Vibration etc.,

There are different types of sensors available for various process variable:

- Thermocouples,
- RTD for Temperature measurement
- Strain gauge,
- Pressure sensing diaphragm,
- capacitive cells for pressure measurement
- Orifice plate,
- Pitot tube,
- Magnetic flow tube etc., for flow measurement

There are so many other sensors used to measure different variables like

- vibration,
- pH,
- force,
- weight etc..,

Transducers:

A transducer converts any form of energy into another form. In electrical instrumentation field Transducers are devices which converts a physical variable into electrical signals. Another name transducers are Pick-ups.

In process control, a converter used to convert a 4–20 mA current signal into a 3–15 psi pneumatic signal is called a current-to-pressure converter.

There are different types of transducer classified based on their working principle.

Transmitters:

Transmitters are devices that convert the signal into a standard signal that can be transmittable through the control loop and the parameters can be monitored remotely.

- Pressure transmitters
- Flow transmitters
- Temperature transmitters
- Level transmitters
- Analytic transmitters

Signals:

Signals are used to transmit process variable from transmitter to the controller and sent back the feedback signal from the controller to the final control elements. There are three types of signal in industrial automation:

Pneumatic signal: Air pressure in the pneumatic pipeline change according to the change in the process variable. The standard pneumatic pressure in the signal pipe in industries are in a range of 3-15psi.

Analog signal: Analog signals are mostly used control signals, the transmitter sends the signal through a set of electrical wire. The standard signal range is within 4-20mA,

for LRV valve a 4mA signal is produced and for URV it is 20mA.Other common standard electrical signals include the 1–5 V (volts)
signal and the pulse output.

Digital signal: Digital signals are special protocols used for communication in industries. All protocol are owned by specific companies, they include Fieldbus foundation, ***Modbus*** from Modicon, Profibus, DeviceNet from Rockwell automation.

Indicators:

An indicator is human readable devices that display the process variable. There are analog indicators such as used in pressure, temperature gauges and there are digital indicators that display process variables as the digits. Even though the process varible is connected to the controller, the indicators are used industries for different purposes.

Recorder:

Recorders are used in industries to provide history on the process and to be submitted to regulatory agencies for verification. By recording the readings of critical measurement points and comparing those readings over time with the results of the process, the process can be improved

Controllers:

Controllers are the centre of process control, which receives process variable then compare with set point stored in the controller and sends a feedback as the controller output to control the final control element. There are pneumatic and electronic or programmable such as DCS, PLC uses a complex mathematical algorithm to perform the control action.

PLC (Programmable Logic Controller):

PLCs are usually computers connected to a set of input/output (I/O) devices. The computers are programmed to respond to inputs by sending outputs to maintain all processes at setpoint.

DCS (Distributed Control Signal):

DCSs are controllers that, in addition to performing control functions, provide readings of the status of the process, maintain databases and advanced man-machine-interface.

Final control element:

Final control elements are the correcting elements that receives signal from the controller and make a change in process to adjust the process variable at the desired parameter. In any control loop, the speed with which a final control element reacts to correct a variable that is out of setpoint is very important. Many of the technological improvements in final control elements are related to improving their response time.

For example:

- Pumbs and Control valves – Final control devices of Flow control system
- Heaters and Boilers – Final control devices of temperature control system
- Compressor and Valves: Final control devices of pressure control system

Actuators:

An actuator is the most important part of the final control element, a device that causes physical change in the final control element. For a valve actuator is the valve stem actuator and for a heater, it is the heating coil. An actuator can be controlled by pneumatically, Hydraulically, Electrically.

Self-Check 2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. is the fundamental building block of the industrial control system or industrial automation..

A. System B. Control loop C. Sensor D. Actuators

2. is the fundamental building block of the industrial control system or industrial automation..

A. System B. Control loop C. Sensor D. Actuators

3._____is converts the transducer output into an electrical quantity suitable for control, recording, and display

A. Recorder C. Signal Conditioner

B. Display device D. Transducer

4._____The measuring element produces a signal related to the control variable(output)

A. Transmitters C. Process element

B. Display device D. Transducer

5._____are devices that convert the signal into a standard signal that can be transmittable through the control loop and the parameters can be monitored remotely

A. Control element C. Correction element

B. Comparison element D. Measuring element

Part II Fill the black space

1. List down Types of Control System (2%)

_____

_____

3. Mention Advantage and Disadvantage of Close loop control system (5%)

_____,_____,_____

_____,_____,_____

_____

. Answer the following question!

Note: Satisfactory rating 9 and 15 points Unsatisfactory below 9 and 17 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date_____

Information Sheet 3. Responding necessary adjustments appropriately

3.1 Responding necessary adjustments appropriately

Safety and calibration Test

Equipment should be in an acceptable physical and working condition at all times, so that it can perform competently and safely. Equipment should not be allowed to deteriorate to such an extent that it becomes untrustworthy or hazardous.

For example:

- frayed mains leads
- disconnected earth
- metal with stress fractures
- leaking gas valves
- cracked glass
- failing brakes
- perished rubber materials.

One strategy is for all staff to regularly check equipment visually for such disintegration, and to report any findings to the Health Care Technology Management (HTM) Team. However, to reduce the risk of such problems, regular testing for electrical and mechanical trustworthiness,

using test instruments, is required. Such testing is known as safety testing, and ensures the safety of equipment.

Another strategy is for all staff to monitor whether equipment is performing as it should be (for example, that an incubator reaches a set temperature, that an autoclave sterilizes its contents, that an X-ray machine produces diagnostic quality X-ray images)– although this is not always obvious. The equipment should then be calibrated to adjust its performance and return it to a set standard. Calibration can
sometimes be undertaken by the equipment users, and sometimes requires the HTM Team.

Safety and calibration instruments are required to enable this process to take place. Safety and calibration testing usually takes place regularly throughout the life of the equipment:

- During the acceptance process when equipment first arrives procurement and commissioning.
- Whenever staff suspect that there may be a problem, or the equipment may not be performing properly.
- Regularly as part of the usual planned preventive maintenance tasks At the end of every repair and corrective maintenance task, whenever equipment breaks down Testing is required for various types of hazard, which are presented by different types of equipment.

For example:

- gas installations need to be tested for gas leaks
- mechanical tests are required to ensure that equipment can withstand its operating conditions such as any pressure, hydraulic, rotation, or heat stresses, and will not break down and create a hazard
- physical checks are required to ensure, for example, that safety guards are replaced on engines so that clothing cannot get caught in machinery
- electrical tests are required for electrical hazards – the major category of hazard –due to electrical installations, earthing, and medical equipment.

Electrical Installations and Earthing

Human bodies are electrical conductors. The passage of electrical current through the body can cause burns or severe muscle cramps, and if electricity flows through the heart it can cause irregular heartbeats and death. Thus obtaining a good quality electrical installation with proper earthing is essential (see Guide 4 on operation and safety).

The electrical installation must be regularly inspected and tested by electricians, using the correct test instruments (see table 2.1). To guarantee the safety of installations, they need to:

- test for earth leakage
- test for circuit continuity
- test for loose connections
- perform insulation tests
- test switch leakages
- test for power
- check for the correct rating
- check whether wiring regulations were followed during installation.

Medical Electrical Safety

Another important area of safety is medical electrical safety. Medical electrical equipment has stricter electrical safety requirements and considerations than non-medical equipment, because it comes into direct contact with patients (for example, ECG recorders, monitors, diathermy units, and physiotherapy ultrasound). All such equipment should conform to (and be manufactured to) the international safety standard IEC 60101 (procurement and commissioning). It describes electro-medical equipment according to the type of protection provided against electric shock (defined as Class I, II, or III), and the degree of protection provided against electric shock (defined as Type B, BF, or CF). You can tell which sort of equipment you have by studying the symbols on the manufacturer's label attached to your equipment. Such equipment will require dedicated safety testing procedures and test instruments, which go further than the standard electrical safety tests described

above. All electro-medical equipment should be regularly inspected and tested by bio-medical technicians, using the correct test instruments (see table 2.1 below).

To guarantee safety, they should perform a variety of tests on each piece of equipment depending on its Class and Type , such as:

- self-checks
- supply voltage check
- insulation resistance test
- earth bonding test
- earth leakage current test
- enclosure leakage current test
- patient leakage current test
- patient auxiliary current test
- mains voltage on the applied part test.

Safety and Calibration Testing Instruments

Safety and calibration testing should be encouraged, even though some of the instruments required are expensive. Most test instruments are used for electrical, electronic, or medical equipment purposes. Since medical equipment has stricter electrical safety requirements and considerations than non-medical equipment, it requires dedicated safety test instruments which go further than simple electrical safety testers. Thus, the HTM Team requires adequate test instruments. Some instruments provide basic tests, while others are designed for more complex procedures. Box 12provides some advice on the types of test instruments required, which are bench-top instruments. Not every HTM Team or workshop needs all of them: it will depend on the skill levels of the staff. However, anyone maintaining or repairing medical equipment needs some form of medical equipment safety tester – either a basic one made from common bench tools or a commercially available product for comprehensive testing (see table 2.1). Other smaller hand tools used for

testing purposes are included in the regular tool kits for maintenance staff table 10 over leaf offers some suggestions for increasing safety and calibration

Table 2.1 overleaf offers some suggestions for increasing safety and calibration testing. However, we recognize that following the suggestions in this figure will require significant resources (money, people, time)

Table 2.1: Example of Safety and Calibration Testing Instruments by Type of Work and Skill Level

Table 2.1:Example of Safety and Calibration Testing Instruments

Type of work	Instrument	Skill level
Electrical	• insulation tester (‘megger’ meter)mains socket wiring tester phase tester	Basic
	• continuity tester three-phase tester	
Electronic	• multimeter	Specialist
	• bench-top power supply counter/timer function generator oscilloscope	
Medical equipment	• ammeter and earth break box (instead of MES tester)electronic • thermometer standard mercury BP apparatus	Basic
	• defibrillator analyzer/tester • ECG simulator • electro-surgical unit (ESU) analyzer • medical electrical safety (MES) tester/analyzer1, 2 • non-invasive BP monitor tester • oxygen analyzer • oxygen flow meter monitor • patient simulator, multi-parameter, two-channel • pH meter standards • phosphorescent strip • pressure/vacuum meters • Spectrophotometer standards	Specialist

	• X-ray line resistance meter • X-ray mAs meter • X-ray phantoms	

Self-Check .3	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. List down the electrical installation must be regularly inspected and tested by electricians . (5%)

_____,_____

_____,_____

_____

2. Mentions To guarantee safety, they should perform a variety of tests on each piece of equipment depending on its Class and Type (5%)

_____,_____

_____,_____

_____,_____

_____,_____

. Answer the following question!

Note: Satisfactory rating 5 and 10 points Unsatisfactory below 5and 10 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet 4. Responding to unplanned events or conditions

4.Responding to unplanned events or conditions

Unplanned events are episodes that are not expected to occur during the Project's normal Construction and Operational Phase activities, such as accidents. The Project follows safety and engineering design criteria that aim to avoid unplanned events that could lead to adverse environmental, socio-economic or health and safety impacts Installing single Phase system, resulting in an Unplanned Event (Commissioning and Operational Phase)

Unplanned learning occurs when an event occurs that causes a learning activity to be undertaken or carried out without any prior thought or planning (e.g. through reading a journal, undertaking an activity or task, or a discussion with a colleague owing to an interaction during your normal working day)

Table : Unplanned Event (Commissioning and Operational Phase)

Activity	Event	Receptors	
		Environmental	Socio Economic & Health
Installing single phase system	short circuit	X	X
	Fires and explosions	X	X
	Shock & injury		X

	Death		X

Based on these considerations, the potential accidents, malfunctions and unplanned events that were considered by the Study Team for the Sisson Project are:

- Loss of Containment from Tailings Storage Facility (TSF)
- Erosion and Sediment Control Failure
- Pipeline Leak
- On-Site Hazardous Materials Spill
- Release of Off-Specification Effluent from the Water Treatment Plant
- Failure of a Water Management Pond
- Failure of a Water Management Pond Pump
- Off-Site Trucking Accident
- Vehicle Collision
- Uncontrolled Explosion
- Fire

4.2. On-Site Hazardous Material Spill

An On-Site Hazardous Material Spill is a spill of materials associated with the Project that is considered to be hazardous due to its inherent physical or chemical properties, or because of its toxicity, flammability, corrosiveness, or explosiveness.

The following measures will be in place to reduce or eliminate the potential for a major release arising from an on-site hazardous material spill:

- The storage of liquid hazardous materials within buildings, in secure Contained areas;
- the provision of impermeable containment berms (or other forms of secondary containment);
- placement of protective barriers as appropriate;
- sitting of such facilities in locations that represent a relatively low risk and afford an opportunity
- for containment during emergency response;
- provision of alarms on secondary containment measures;
- careful implementation of fuel transfer operations; and

- Provision of an emergency response plan for the immediate isolation and clean-up of a release.

4.3. ASSESSMENT OF ACCIDENTS, MALFUNCTIONS, AND UNPLANNED EVENTS

4.3.1Electrical Hazard

The risk of an electrical hazard has the potential to interact with terrestrial environment and socioeconomic environment. Live high voltage conductors pose the risk of injury or death to individuals or wildlife if contacted directly or indirectly. Mitigation measures to minimize the risk of electrical injuries to those in or proximate to a power transmission corridor are not generally a requirement for land-based transmission, given the height of conductors. Downed conductors can allow for the potential interaction of live electrical cables with personnel or wildlife in the area. Unauthorized access to secure locations can also put individuals at risk of electrocution.

4.3.2.Risk Management and Mitigation

The following mitigation measures will be applied to reduce the probability of an electrical hazard and associated environmental effects.

- During the operation phase of the Project, Project components will be inspected periodically and repaired as required.
- Safe operating procedures will be established for all work activities, both during the construction and operation phases of the Project.
- NB Power's safety and environmental policies will be followed.
- Proper signage and public warning will be installed around project land-based components/facilities (e.g., "High Voltage").
- Access to the work site during construction and energizing activities will be limited to NB Power and their consultants and required contractor crews.
- Physical safeguards such as security fences surrounding facilities will be implemented.
- Access to facilities will be restricted to authorized personnel only.
- The use of appropriate down lighting will be incorporated around Project components (e.g., cable riser stations) to discourage vandalism and loitering.

4.3.1.3 Potential Residual Environmental Effects and their Significance

If an electrical hazard incident were to occur, the terrestrial environment and socioeconomic environment could be affected. As the submarine cables will be buried in

the near shore environment (i.e., between the shore and the cable riser stations) and the cable riser stations will be fenced in, the probability of an electrical hazard incident is low because there is limited opportunity for individuals or wildlife to be exposed to them. Therefore, potential environment effects arising from electrical hazards on the terrestrial or socioeconomic environments are not anticipated to be substantive. In consideration of the buried nature of the cables in areas accessible to the public and wildlife, and in light of the mitigation to be implemented, the residual environmental effects of an electrical hazard during all Project phases are rated not significant for all potentially affected VCs. This determination is made with a high level of confidence. There is the potential that a protected species or person could be harmed or even killed were they to come in contact with the energized electrical components of the Project, and this would represent a significant residual environmental effect; however, given the safeguards in place, this is a highly unlikely scenario. Consequently, a significant environmental effect arising from this possibility is also considered to be unlikely to occur.

Self-Check 4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part I Fill the black space

1. List down Risk Management and Mitigation measures will be applied to reduce the probability of an electrical hazard and associated environmental effects(5%)

_____

_____,_____

_____,_____

_____,_____

2.. What is On-Site Hazardous Material Spill? (5%)

_____

_____

_____

_____

_____

. Answer the following question!

Note: Satisfactory rating 5 and 10 points Unsatisfactory below 5 and 10 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

LG #25	LO3. Repair Biomedical Equipment Control Systems(BMECS)

Instruction sheet

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Checking normal function of BMECS.
- Diagnosing fault/s or problem/s in BMECS
- Responding to necessary adjustments.
- Responding to unplanned events or conditions
- Using appropriate **PPE**.

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Check normal function of BMECS.
- Diagnose fault/s or problem/s in BMECS
- Respond to necessary adjustments.
- Respond to unplanned events or conditions
- Use appropriate **PPE**.

Learning Instructions:

1. Read the specific objectives of this Learning Guide.
2. Follow the instructions described below.
3. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them
4. Accomplish the “Self-checks” which are placed following all information sheets.
5. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
6. If you earned a satisfactory evaluation proceed to “Operation sheets
7. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
8. If your performance is satisfactory proceed to the next learning guide,
9. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet 1. Checking normal function of BMECS.

1. **Check normal function of BMECS.**

Any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including the software necessary for its proper application intended by the manufacturer to be used for human beings for the purpose of:

- diagnosis, prevention, monitoring, treatment or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of or compensation for an injury or handicap,
- investigation, replacement or modification of the anatomy or of a physiological process,

- control of conception, and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted in its function by such means

1.1. **Troubleshooting**

- To isolate the source of a problem and fix it, typically through a process of elimination whereby possible sources of the problem are investigated and eliminated beginning with the most obvious or easiest problem to fix.
- In the case of computer systems, the term *troubleshoot* is usually used when the problem is suspected to be hardware-related. If the problem is known to be in software, the term *debug* is more commonly used.

1.2. **How can a medical device be Troubleshooted?**

- Be able to read and understand the Service's and User's Manuals
- Be able to use biomedical hand tools.
- Be able to use multimeter (Voltmeter, Ammeter, Ohmmeter..)
- Be able to use Oscilloscope

1.3. Service's and User's Manuals

1. **Service's Manual:** provides useful information to Qualified Service Personal (QSP) to understand, troubleshoot, service, maintain and repair a medical equipment (device)
2. **User's Manual:** helps the medical staff to operate a medical device

1.3.1. Sections of Service's Manual

- General
- Maintenance
- Troubleshooting
- System Test
- Board description
- Disassembly and Assembly
- Replaceable Parts List
- How to reach the manufacturer

1.3.2. Conventions in Service's Manual

- **WARNING**: a warning alerts the user to the possible injury or death associated with the use or misuse of the instrument.
- **CAUTION:** a caution alerts the user to possible injury or problems with the instrument associated with its use or misuse such as instrument malfunction, instrument failure, damage to the instrument, or damage to other property.
- **NOTE:** a note provides specific information, in the form of recommendations, pre requirements, alternative methods or supplemental information.

1.5. Troubleshooting and System Error Message

1.5.1. Troubleshooting Flowchart:

Use the troubleshooting flowchart to find the possible sources of a problem.

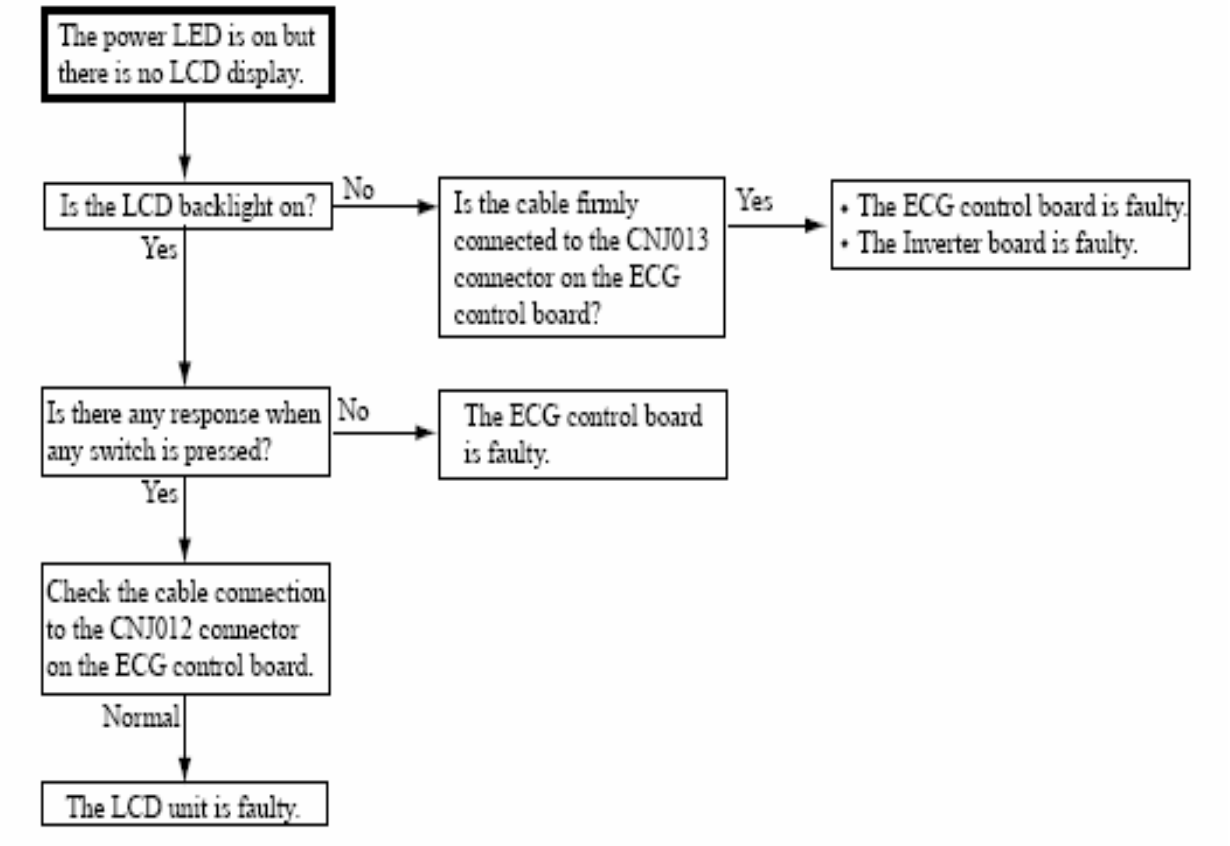


Figure 1.1 Troubleshooting Flowchart

1.5.2 Troubleshooting Table

Use the troubleshooting table to locate, identify and solve a problem in the instrument. The problems are divided into general operation and recording. Each category has its own troubleshooting table for fast and easy troubleshooting.

How to use the troubleshooting table

1. Determine which troubleshooting table to use.
2. In the “Problem” column find the trouble item that matches the problem.
3. Do the action recommended in the “Corrective Action” column.
4. If the problem is not solved, do the action for the next possible cause or criteria.
5. If none of the actions solve the problem, contact dealer

1.5.3. System Error Message

During power-up and operation the instrument continuously checks itself for system failure. If a failure is detected, system information and error history are printed on the recording paper and all operations are stopped. System information and error history are also displayed or printed due to transient noise. After printing the system information and error history, the power of the instrument is automatically turned off.

1.6. System Test, Adjustment, and Setting

1.6.1 System Test:

Test level 1

- •Demonstration
- •Recorder
- •Key*
- •Memory*
- •LCD*
- •Input unit*
- •Calibration*
- •Communication*
- •CRO/EXT1*
- •System Setup Initialization*
- •ECG Findings List Recording

Test level 2

- •Recorder
- • Thermal head
- •Recording resolution setting
- •Key*
- •Memory (single)*
- •Memory (continuous)
- •LCD*
- •Input unit*
- •Calibration*
- •Communication*
- •CRO/EXT1*
- •System Setup Initialization*
- •Cue mark adjustment

Demonstration

This is used to learn or teach instrument operation. While executing this test item, the instrument generates dummy 12 lead ECG

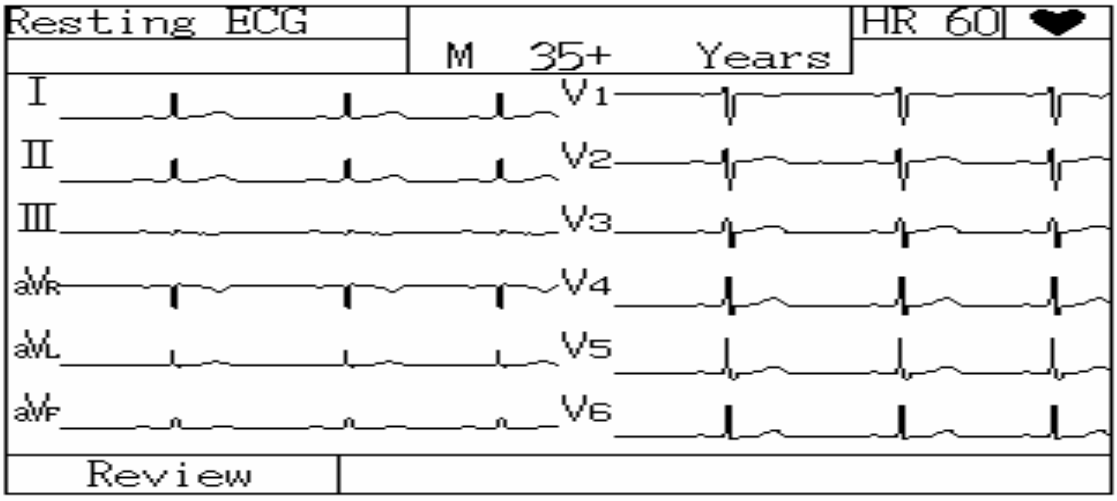


Figure 1.2 Generates dummy 12 lead ECG

Recorder

This is used to check the condition of the recorder by printing test patterns. The recording test patterns consist of the following and are printed in the following order:

1. Diagonal lines (Check Thermal Head)
2. Characters H and X(Check Thermal Head)
3. Grid (Check ECG control B.)
4. Paper speed scales (10, 12.5, 25 and 50 mm/s) (Check Motor, Gear, Sensor)
5. Paper mark detection (Check Sensor)

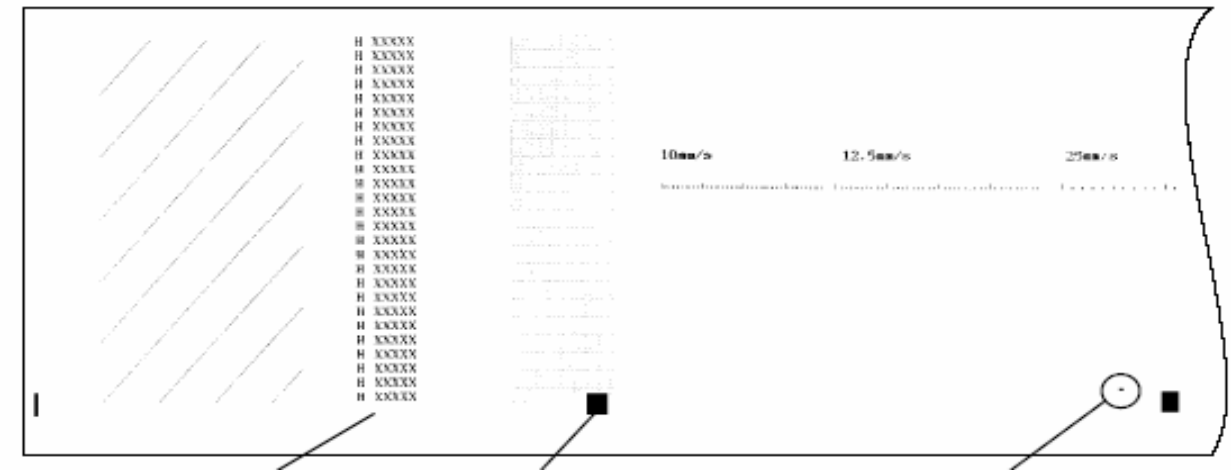


Figure 1.3. check the condition of the recorder by printing test patterns

Thermal Head

This is used to check the condition of the thermal head by printing out the characters “H” and “X” continually.

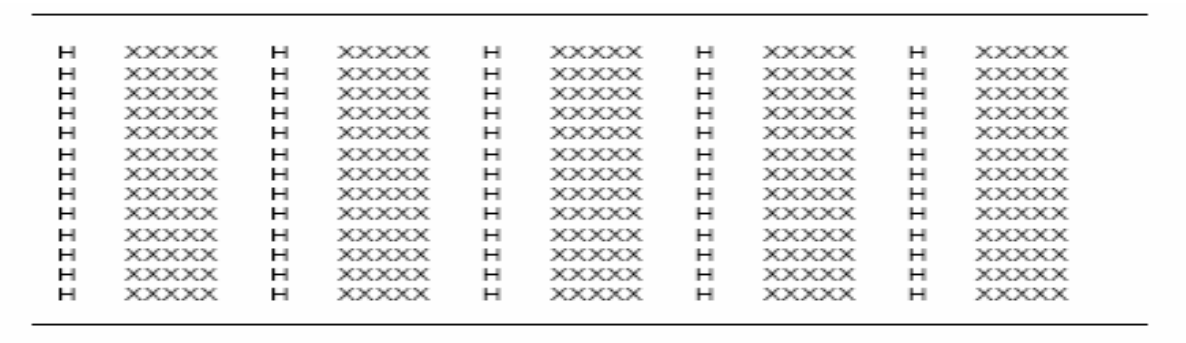


Figure 1.4. check the condition of the thermal head

Key This is used to check the condition of the keys on the operation panel.

Possible Source of Problem	Corrective Action
Damaged membrane key.	Replace the membrane key.

Figure 1.5. check the condition of the keys on the operation panel

Memory

This is used to check the condition of the memory by comparing the data of the test patterns written to and read from each memory area.

Memory test result (Count of test: 1)

		Error count
Main memory (BIT/ADR)	OK	0
Recorder memory (BIT/ADR)	Error (E88004/000000h)	1
VRAM (BIT/ADR)	Error (C10000h/C10004h)	1
Program ROM	OK	0
Flash memory	NONE	0
Input unit SRAM	Error	1
Input unit ROM	OK	0
Input unit EEPROM	OK	0
File memory	Error	1
Hospital	NIHON KOHDEN HOSPITAL	
Model	9020K	
Version	01-01	
Input unit version	01-01	
Analizing version	01-01	
Date	Apr 24, 1998 10:41 AM	
Cardiograph internal temp	46.5 C	
Elapsed time	0 hours	
Thermal head temperature	36.0 C	
Battery voltage	13.4 V	

Figure 1.6.check the condition of the memory by comparing the data of the test patterns

LCD

The LCD displays the following four types of test patterns every two seconds in the following order:1. Diagonal lines are displayed.2. Entire LCD lights up.3. LCD is completely dark but backlight lights.4. Backlight does not light.

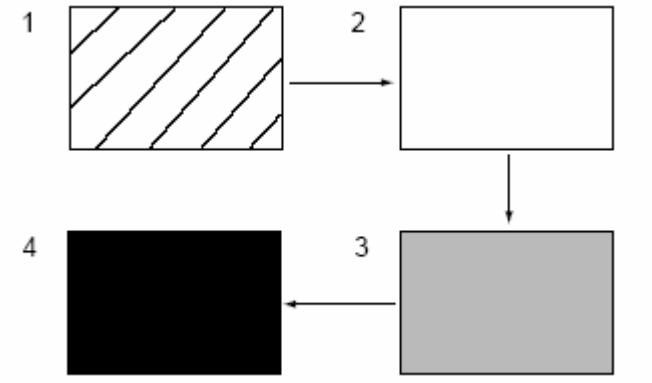


Figure 1.7.LCD displays the following four types of test patterns

Calibration

Amplitude when CAL waveform is risen: 10 mm±2%•Amplitude of point which is 25 mm more than 7.3 mm from the rising point of the CAL waveform

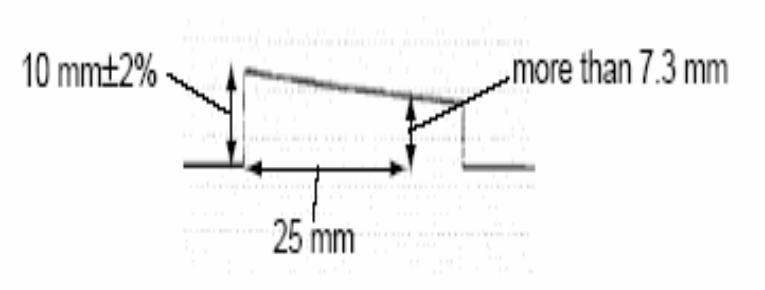


Figure 1.8.Calibration

1.7. **Board/Unit Description**

1.7.1. Power Unit

The Power unit consists of the power source, battery charging and control circuits. The Power unit uses the switching regulation method to produce the power required for the instrument.

1.7.2. Flash ROM Board

The Flash ROM board has a 2 MB flash ROM for writing the control program, analysis program, Japanese font and English font to the ROM. Also, there is a space for mounting an EEPROM.

1.7.3. ECG Control Board

The ECG Control board consists of the following components: Component Description

CPU: MC68EC020 (Operating frequency: 25 MHz)

ROM: For system software, 2 MB

DRAM: Main memory, 1 MB

Flash memory: For font of local language, 1 MB For filing data, 256 KB

Real time clock: For monitoring back-up battery, built-in 140 B SRAM

Timer: 1 ms timer

Interrupt request signal ON/OFF: selectable

Operation mode: fixed

Serial interface: Equivalent to RS-232C, 1 channel

Baud rate: 2,400 to 115,200 bps selectable

Speaker circuit: Beep sound, Sound by noise generator

Interrupt request: Auto-vector method

Interface: To ECG input section

Recorder:

LCD:

Controller: For key board

A/D converter:

Self-Check 1	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. How can a medical device be Troubleshooted

A. read and understand the Service's and User's Manuals

B. use biomedical hand tools

C. use multimeter (Voltmeter, Ammeter, Ohmmeter..)

D. All correct

2._____provides useful information to Qualified Service Personal (QSP) to understand, troubleshoot, service, maintain and repair a medical equipment (device)

A. User manuals C. Service manuals

B. Flowchart D. Calibration

3._____helps the medical staff to operate a medical device

A. Memory C. Corrective Action

B. Service manuals D. User manuals

. Answer the following question!
Note: Satisfactory rating 3 and 6 points Unsatisfactory below 3 and 6 points
You can ask you teacher for the copy of the correct answers.

Score = _____
Rating: _____

Answer Sheet

Name: _____ Date_____

Information Sheet 2 Diagnose fault/s or problem/s in BMECS

2.1 Diagnose fault/s or problem/s in BMECS

Troubleshooting: is sometimes thought to be the simple repair of a piece of equipment when it fails to function properly. This, however, is only part of the picture. In addition to repair, you, as a troubleshooter, must be able to evaluate equipment performance. You evaluate performance by comparing your knowledge of how the equipment should operate with the way it is actually performing. You must evaluate equipment both before and after repairs are accomplished.

Equipment performance data, along with other general information for various electronic equipment's, is available to help you in making comparisons. This information is provided in performance standards books for each piece of equipment. It illustrates what a particular waveform should look like at a given test point or what amplitude a voltage should be, and so forth. This data aids you in making intelligent comparisons of current and baseline operating characteristics for the specific equipment assigned to you for maintenance. ("Baseline" refers to the initial operating conditions of the equipment on installation or after overhaul when it is operating according to design.)

6.2. Principle of troubleshooting

- Systematic approach to locating the cause of a fault in an electronic circuit or system
  - ✓ If your keyboard will not type, check to ensure that the cable is securely fastened to the keyboard port
- Determining which part of a system is responsible for a problem
  - ✓ Sensing electrode, reference electrode, instrument, solution, measuring technique and operator. Unexpected solution chemistry, incorrectly prepared standardizing solutions, improper plotting of data, unsuitable reference electrodes, operator error and poor choice of method account for many more problems than do instrument or electrode failure.
- A logical way of testing hardware or software in order to determine how to fix a problem

6.3. Logical Approach to Troubleshooting

- Troubleshooting is done by one of the following methods:
  - ✓ Case-study approach is used if a piece of equipment were known to have a chronic, or repetitive, problem. Check to see if it had reoccurred before looking for other problems.
  - ✓ Logical analysis of given evidence. Data relating to the problem is gathered and used to isolate the case analytically. Because circuit theory is basic to design of medical equipment, it could be used to deduce every problem with the hardware.Systematic approach to troubleshooting uses both methods.
- Repair procedure will involve systematic disassembling and reassembling of the equipment.
  - ✓ To disassemble the equipment, number each part as you remove it.
  - ✓ Then to reassemble, replace the parts in the reverse order, in order to be sure you are putting all the parts back together correctly.

2.4. Circuit Board Troubleshooting

- When a circuit board has been found to be faulty, component-level troubleshooting should be done. This involves:
  - ✓ Detailed signal tracing
  - ✓ Voltage and resistance measurements
  - ✓ Use of the equipment schematic showing interconnection between the individual components.
- If a particular circuit board should be replaced by a another one, the following consideration should be taken:
  - ✓ A visual inspection should be performed to look for any evidence of short circuits or overheating.
  - ✓ Checking the power supply over-voltage, which could be damage the new board.
  - ✓ Using of antistatic spray to prevent damage due to static chargebuildup.
  - ✓ Because the circuit boards are expensive, all precautions shouldbe taken not to damage them during troubleshooting procedures.

2.5. Transducers troubleshooting

- Since they are the contact point between the patient and the instrument, transducers are often vulnerable to damage.
- Troubleshooting techniques apt to be effective with transducers are visual inspection, interview of the operator, and voltage or resistance measurement.
- Since transducers are often moved about and have delicate parts, they are subject to wear and abuse.
- Surface electrode:
  - ✓ Check its attachment to the skin to make sure the electrode gel is adequate and has not dried out
  - ✓ Be sure from the adhesive connection
  - ✓ No excessive hair under the electrode, or a scarred or bony surface
  - ✓ Visual inspection of cable connections for frays, breaks, or corrosion may reveal a problem

2.5.1. Thermistors:

- Poor thermal conductivity between the body tissue monitored and the thermistor.
- Be sure that the mechanical connection free of air gaps
- In case that the thermistoris a branch of a Wheatstone bridge, a voltage check of the bridge output and resistance measurements on its components could reveal thermistor related faults
- Non linearity of the thermistor, for example, could be caused by a failure in a linearizing resistor attached across the thermistor
- The sensitivity of the thermistor can be effected by:
    - ✓ Faults in the bridge branch components
    - ✓ Drop in the excitation voltage of the bridge

- To isolate the problem it can be used circuit analysis, voltage or resistance checks
- The final proof that a component is faulty is that changing the part either changes the symptoms of the problem or causes it to disappear

2.5.2. Strain gauge:

- Troubles in this transducers are affected by mechanical contact with the patient
- Elimination of these problems is usually the responsibility of the equipment operator
- Problems with the balancing bridge and the excitation voltage are similar to those affecting the thermistor
- Because the operation of pressure transducer often depends on the measuring pressure transmitted through a fluid column (especial in INBP), any air bubbles in the line seriously degrade both the transducer sensitivity and its frequency response
- Bubbles often can be seen visually, and flushed and that must bedone when the transducer is removed from the patient to remove any hazard of transferring bubbles into the bloodstream

Self-Check 2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part I Fill the black space

1. List down When a circuit board has been found to be faulty, component-level troubleshooting should be done (4%)

_____

_____

_____

_____

_____

_____

2. List down Principle of troubleshooting (6%)

_____,_____

_____,_____

_____,_____

_____,_____

. Answer the following question!

Note: Satisfactory rating 6 and 10 points Unsatisfactory below 6 and 10 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____
Rating: _____

Name: _____ **Date:** _____

Information Sheet 3. Respond to necessary adjustments.

3. Respond to necessary adjustments

3.1. Procedure of calibration

Manual and automatic calibration procedure

Calibration methods for modern devices can be both manual and automatic, depending on what kind of device is being calibrated.

Manual calibration US: serviceman calibrating a temperature gauge. The device under test is on his left and the test standard on his right.

Manual

Manual calibration procedure on a pressure test gauge. The procedure is complex, but overall it involves the following: depressurizing the system, and turning the screw, if necessary, to ensure t**hat the needle reads zero,** fully pressurizing the system and ensuring that the needle reads maximum, with**in acceptable tolerances,** replacing the

gauge if the error in the calibration process is beyond tolerance, as this may indicate signs of failure such as corrosion or material fatigue.

Automatic calibration

The use of a 3666C automatic pressure calibrator, which is a device that consists of a control unit housing the electronics that drive the system, a pressure intensifier used to compress a gas such as Nitrogen, a pressure transducer used to detect desired levels in a hydraulic accumulator, and accessories such as liquid traps and gauge fittings.The Calibration Process. There are a number of stages in the process of calibrating an analytical instrument.

These are summarized below:

- Plan the experiments;
- Make measurements;
- Plot the results;
- Carry out statistical (regression) analysis on the data to obtain the calibration function;
- Evaluate the results of the regression analysis;
- Use the calibration function to estimate values for test samples;
- Estimate the uncertainty associated with the values obtained for test samples.

3.2. Process description and documentation

All of the information above is collected in a calibration procedure, which is a specific test method. These procedures capture all of the steps needed to perform a successful calibration. The manufacturer may provide one or the organization may prepare one that also captures all of the organization's other requirements. There are clearing houses for calibration procedures such as the Government-Industry Data Exchange Program (GIDEP) in the United States.

This exact process is repeated for each of the standards used until transfer standards, certified reference materials and/or natural physical constants, the measurement standards with the least uncertainty in the laboratory, are reached. This establishes the traceability of the calibration.

See Metrology for other factors that are considered during calibration process development.

After all of this, individual instruments of the specific type discussed above can finally be calibrated. The process generally begins with a basic damage check. Some organizations such as nuclear power plants collect "as-found" calibration data before any maintenance is performed. After routine maintenance and deficiencies detected during calibration are addressed, an "as-left" calibration is performed.

More commonly, a calibration technician is entrusted with the entire process and signs the calibration certificate, which documents the completion of a successful calibration. The basic process outlined above is a difficult and expensive challenge. The cost for ordinary equipment support is generally about 10% of the original purchase price on a yearly basis, as a commonly accepted rule-of-thumb. Exotic devices such as scanning electron microscopes, gas chromatograph systems and laser interferometer devices The 'single measurement' device used in the basic calibration process description above does exist. But, depending on the organization, the majority of the devices that need calibration can have several ranges and much functionality in a single instrument.

3.3. Linear instruments

The simplest calibration procedure for a linear instrument is the so-called zero-and-span method. The method is as follows: Apply the lower-range value stimulus to the instrument; wait for it to stabilize Move the zero adjustment until the instrument registers accurately at this point.

Apply the upper-range value stimulus to the instrument, wait for it to stabilize

Move the span adjustment until the instrument registers accurately at this point.

Repeat steps1 through as necessary to achieve good accuracy at both ends of the range

An improvement over this basic procedure is to check the instruments response at several points between the lower-and upper- range values.

A common example of this is the so-called five-point calibration where the instrument is checked at 0% (LRV), 25%, 50%, 75%, and 100% (URV) of range.

A variation on this theme is to check at the five points of 10%,25%, 50%, 75% ,and 90%, while still making zero and span adjustments at 0% and 100%.

Regard less of the specific percentage points chosen for checking, the goal is to ensure that we achieve (at least) the minimum necessary accuracy at all points along the scale, so the instruments response may be trusted when placed into service.

Yet another improvement over the basic five-point test is to check the instruments response at five calibration points decreasing as well as increasing. Such tests are often referred to as Up- down calibrations. The purpose of such a test is to determine if the instrument has any significant hysteresis: a lack of responsiveness to a change in direction.

Self-Check 3	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II Fill the black space

1. What is the difference Manual and automatic Calibration (5%)

_____,_____

2. List Down a number of stages in the process of calibrating an analytical instrument(5%)

_____,_____

_____,_____

. Answer the following question!

Note: Satisfactory rating 5 and 10 points Unsatisfactory below 6 and 10 points

You can ask you teacher for the copy of the correct answers.

Score = _____
Rating: _____

Answer Sheet

Name: _____ Date: _____

Information Sheet 4 Respond to unplanned events or conditions

4. 1. Respond to unplanned events or conditions

Unplanned events are accidents or upset events or conditions that are not planned as a part of routine Project activities during any Project phase. Even with the planning and application of mitigation, accidents, malfunctions, and unplanned events could occur during any phase of the Project. These could occur as a result of abnormal operating conditions, wear and tear, human error, equipment failure, and other possible causes. Many accidents, malfunctions, and unplanned events are preventable and can be readily addressed or prevented by good planning, design, equipment selection, hazards analysis and corrective action, emergency response planning, and mitigation.

In this section, the potential accidents, malfunctions, and unplanned events that could occur during any phase of the Project and potentially result in significant adverse environmental effects are described, discussed, and assessed. The focus is on credible accidents that have a reasonable probability of occurrence, and for which the resulting residual environmental effects could be major without careful management.

It is noted that accidents, malfunctions, and unplanned events are evaluated individually, in isolation of each other, as the probability of a series of accidental events occurring in combination with each other is very minimal. These possible events, on their own, generally have a very low probability of occurrence and thus their environmental effects are of low likelihood. They have an even lower probability or likelihood of occurring together – thus their combination is not considered credible, nor of any measurable likelihood of occurrence.

Accidents, malfunctions, and unplanned event scenarios have been conservatively selected that represent higher consequence events that would also address the consequences of less likely or lower consequence scenarios. The accidents, malfunctions, and unplanned events that have been selected based on experience and professional judgment are as follows:

- Worker accident: worker accidents may occur during either construction or operation, and may result in harm, injury, or death to one or more Project workers;
- Fire: consists of a fire in a Project component. The focus is on the consequence, and not the mechanism by which it occurs;
- Electrical Hazardous materials spill: spills of fuel, petroleum products, and/or other chemicals used on site or in Project components; and

1. Worker accident

A worker accident has the potential to interact with communities as it may result in harm, injury, or death to workers. All workers will be properly trained in practices to prevent workplace accidents including Workplace Hazardous Materials Information System (WHMIS), first aid, and other applicable training programs. These procedures are designed to prevent serious injury to staff and the general public as well as to minimize

the occurrence of unplanned events and minimize any potential damage to the environment.

Interactions between a worker accident and communities will be mitigated by compliance with health and safety legislation, safety by design, and implementation of environmental management measures aimed at protecting human health. Safety risks to workers will be reduced by complying with the requirements of various governing standards including the federal Canada Labour Code, the federal *Transportation of Dangerous Goods Act*.

Workplace Health and Safety Act and all associated regulations. Adherence to public safety codes and regulations will help the Project to be carried out in a safe manner to protect workers and the public.

With the application of, and compliance with, these acts, regulations, and standards, including the application of safety and security measures that are known to effectively mitigate the potential environmental effects, the potential environmental effects of a worker accident on communities during construction and operation and maintenance of the Project are assessed as minor.

2. Fire

A fire at the Project location could interact with the atmospheric environment (smoke emissions), infrastructure and services (stress on services) communities (potential safety risks to workers), land use and property (potential for substantive loss or damage to property of resources), and the aquatic, wildlife and natural vegetation environments (potential contamination with sediment-laden water used in extinguishing the fire).

A fire may arise from Project heavy equipment or from natural causes such as a lightning strike. In the unlikely event that a fire occurred, the immediate concern for a fire would be for human health and safety. Local air quality conditions may deteriorate through the duration of the fire.

Personnel will take the necessary precautions to prevent fire hazards when at the work site and will keep the site free of all flammable waste. Manitoba Hydro will ensure that personnel are trained in the use of fire-extinguishing equipment. In the unlikely event of a fire, local emergency response will be able to reduce the severity and extent of damage.

The emissions from a fire would likely consist mainly of smoke (particulate matter) and CO2 but could also include CO, NO2, SO2, and other products of incomplete combustion. A large fire could create particulate matter levels greater than the ambient air quality standard over distances of several kilometers, but such situations would be of short duration, infrequent, and are not expected to occur because of planned mitigation and prevention measures. The potential residual environmental effects of a fire are therefore assessed as minor.

3. Electrical Hazardous

Safety measurements are not limited to your residential places you have to keep these parameters sustain in your office area too. Various electric appliances are being used already in your place where printers, monitors, and other electronic applications are plugged into the non-efficient power cord. This kind of practice can be dangerous. Multiple numbers of employees need to have the proper training to prevent their self and fellows. Numerous accidents are taken place due to faulty equipment or some of the material which is missing. In this blog, I am going to let you know how to keep your workplace safe from severe kind of electrical hazards suggested by Electrical Safety Foundation International. Let's have a look

Power Cord should be of High quality:

Power cord which is being considered to utilize must be of some renown brand, should be of high quality. Purchase your product from reputable retailer

Installation place:

You need to install power strips in such location where air passage should be at best to scatter heat because too much heat may cause short circuits in wiring that's why this is suggested to keep away from the heating area.

Avoid overloading in outlets:

Usually, you may have seen in your workplace where high voltage appliances are plugged into one outlet, so it is suggested to avoid too much overloading

Inspect Electrical cords:

It better to keep an eye on electrical wires they shouldn't be cracked or damaged so check electrical cords once in a month.

Avoid binding and knotting cables:

You need to avoid binding and knotting the wires because it may produce electric shocks which would be a hazard for your workplace.

Unused appliances need to be unplugged:

Unused electrical items need to be unplugged until for further use. Because it will increase the electricity consumption

Avoid maintaining by yourself:

You don't need to support this thing by yourself because it can be dangerous for you and it may produce electrical shocks. So you can have the assistance of Electricians Barrow in Furness or nearby areas who know all the safety measurements very well, and they will keep on guiding your employees for do's and don'ts.

Licensed electricians:

You need to hire licensed electricians who should have proper information and qualification before playing with wires.

Don't route power cords under the carpets:

This is not suggested to install power cords under the rugs. Because employees are rolling the chairs here and there for work purpose and when chairs roll over them it would be risky for your employees.

Disconnect electrical equipment:

If there are electrical equipment is malfunctioning, and you feel terrible smell then disconnect all the electrical equipment which is plugged into a socket on urgent basis.

These are all the essential safety parameters which you should follow because you are spending probably 7–8 hours daily and some avoidance will put your life at risk. On the other hand, you must ensure your electrics PAT testing from Barrow in Furness for your life safety. Major incidents are figured out due to such dodging acts from the organization, and they take these measurements for granted.

So keep your workplace risk free at any cost.

Self-Check 4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II Fill the black space

1. What is Unplanned events? (7%)

_____,_____,_____,_____
_____,_____,_____

2. What are the accidents, malfunctions, and unplanned events that have been selected based on experience and professional judgment ? (5%)

_____,_____

_____,_____

. Answer the following question!

Note: Satisfactory rating 8 and 14 points Unsatisfactory below 8 and 14 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet 5 Use appropriate PPE

5. Use proper PPE according to company requirements

5.1.Use personal protective equipment (PPE)

Devices used to protect employees from injury or illness resulting from contact with chemical, radiological, physical, electrical, mechanical, or other workplace hazards.

The need for PPE and the type of PPE used is based on hazard present; each situation must be evaluated independently. Examples of PPE include ear muffs, respirators, face masks, hard hats, gloves, aprons and protective eyewear. PPE limits exposure to the harmful effects of a hazard but only if workers wear and use the PPE correctly.

Information about suitable controls for many common hazards and risks can be obtained from:

- Codes of practice and guidance material
- Manufacturers and suppliers of plant, substances and equipment used in your workplace.

PPE is used as a last resort to avoid risk in work place.

The use of PPE signifies that the hazard could not be controlled by other methods, such as: administrative controls, engineering or industrial hygiene controls. The use of PPE signals that the hazard still exists in the workplace unprotected individuals in the same area will be exposed.

Failure of PPE means that the worker will be exposed. PPE type depends on hazard to be protected.

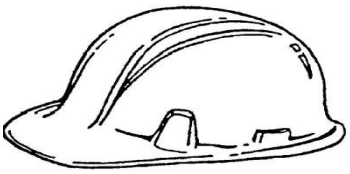
Head protection

Protective helmets (hard hats) come in a variety of shapes. They may be made of tough polyethylene or polycarbonate, one of the toughest hat materials yet developed. Regular hard hats must be insulated so that personnel may be protected from accidental head contacts with electrical circuits and equipment at comparatively low voltages (less than 2200 volts).

Figure 5.1 helmet

Eye and Face protection Common Uses:

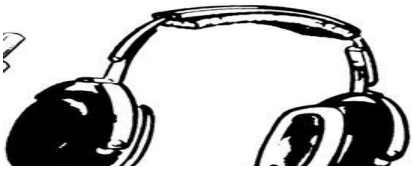
- Impact Protection
- Chemical Hazards
- Radiation Protection
- Eye and Face Protection device
- welder's goggles
- laser goggles
- UV
- Infrared



Safety glasses are used to protect the eyes from flying

objects.

Chemical splash goggles protect against fluids by sealing tightly against the face



Face shields provide highest level of protection

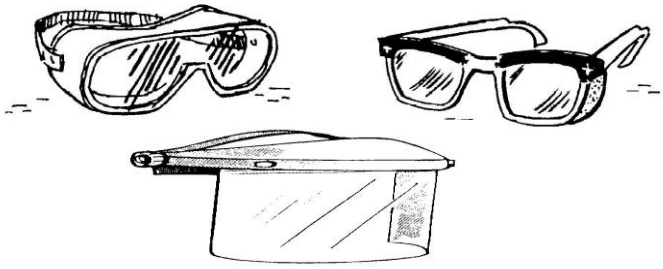


Figure 5.2 Eye goggles

Hearing Protection

Noise induced hearing loss can occur with exposures >90 dB. All hearing protection devices should have a Noise Reduction Rating (NRR) of decibels they will reduce noise levels.

Types

Ear Plugs - less expensive, disposable, good ones have fairly high NRRs - sometimes difficult to tell if employees are wearing them

Ear Muffs - more expensive, more durable, typically higher NRRs than plugs, more obvious.

Figure 5.3 Ear Muffs

Arm and Hand protection

Gloves - Typical Uses Chemical protection Biohazard protection Friction protection

Protection from extremes of heat and cold.

Types

- Surgical gloves
- Electrical gloves

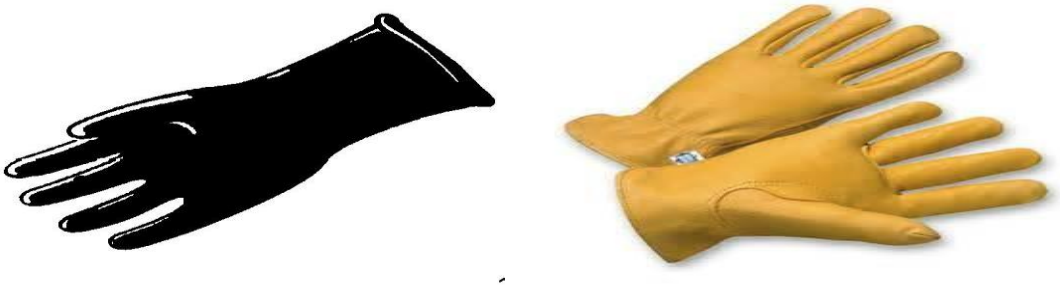


Figure 5.4 Surgical gloves

Foot and Leg protection

Steel-toed footwear, preferably with metatarsal guards, is used to protect feet from crushing injuries caused by heavy objects

Rubber boots are often used to protect feet from exposure to liquids.

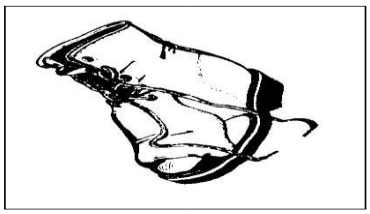
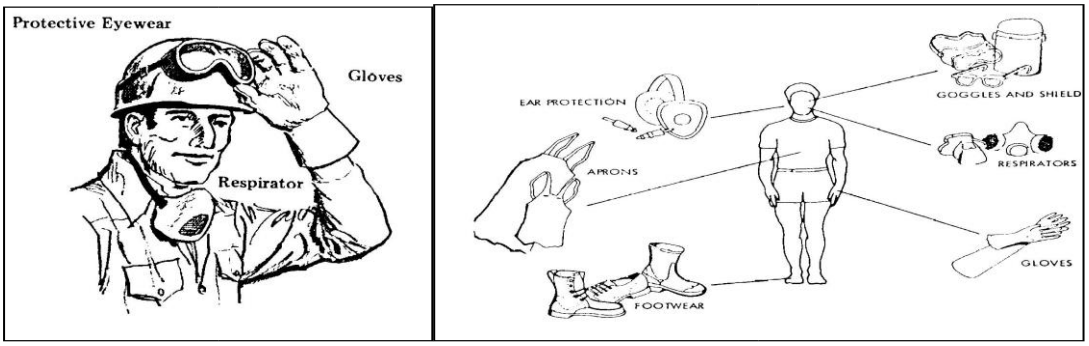


Figure 5.5 Foot and Leg protection

Respiratory protection

Protects users by removing harmful materials that may enter the body via the lungs. Inhalation is one of the quickest, most efficient ways to introduce lethal levels of hazardous materials into the body.



Selection and Use of Chemical Disinfectants Alcohols (ethanol, isopropanol)

Ethanol or isopropanol in concentrations of 70% - 95% are good general-use disinfectants. They are most effective against lipophilic viruses, less effective against non-lipid viruses, and ineffective against bacterial spores. Because of their quick evaporation rate, it may be difficult to achieve sufficient contact time.

Disinfectants Defined: - Disinfecting agents are registered by the Environmental Protection Agency (EPA) as “antimicrobial pesticides” and are substances used to control, prevent, or destroy harmful microorganisms (i.e., bacteria, viruses, or fungi) on inanimate objects and surfaces. These antimicrobial products have traditionally included sanitizers, disinfectants, and sterilants.

Self-Check 5	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What are the common uses of Eye and Face protection are

   A. Impact Protection C. Radiation Protection

B. Chemical Hazards D. All

2. Uses Chemical protection, Biohazard protection, Friction protection from extremes of heat and cold?

   A. Glove C. Hearing Protection

   B. Head protection D. Eye and Face protection

3. PPE used to protect employees from injury or illness resulting from contact with, electrical, mechanical, or other workplace hazards.

   A. Chemical C. physical

   B. Radiological D. All

4. One of the following is **not** the protective device?

   A. welder's goggles C. laser goggles

   B. Infrared D. None

5. Which one of the following are the types of Hearing Protection?

   A. Ear Plugs C. Ear glove

   B. Ear Muffs D. A & B

. Answer the following question!

Note: Satisfactory rating 8 and 14 points Unsatisfactory below 8 and 14 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____
Rating: _____

Name: _____ Date: _____

LG #26	**LO4. Inspect and test the repaired Biomedical Equipment Control Systems**
Instruction sheet	

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Inspecting BMECS to ensure safe operation.
- Conducting appropriate functional test.
- Cleaning and clearing work site.
- Recording test results in history cards.
- Preparing and completing report

Preparing and complete report.This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Inspect BMECS to ensure safe operation.
- Conduct appropriate functional test.
- Clean and clearing work site.
- Record test results in history cards
- Prepare and complete report

Learning Instructions:

10. Read the specific objectives of this Learning Guide.
11. Follow the instructions described below.
12. Read the information written in the “Information Sheets”. Try to understand what are being discussed. Ask your trainer for assistance if you have hard time understanding them
13. Accomplish the “Self-checks” which are placed following all information sheets.
14. Ask from your trainer the key to correction (key answers) or you can request your trainer to correct your work. (You are to get the key answer only after you finished answering the Self-checks).
15. If you earned a satisfactory evaluation proceed to “Operation sheets
16. Perform “the Learning activity performance test” which is placed following “Operation sheets” ,
17. If your performance is satisfactory proceed to the next learning guide,
18. If your performance is unsatisfactory, see your trainer for further instructions or go back to “Operation sheets”.

Information Sheet1. Inspect BMECSs to ensure safe operation.

1. Inspect BMECSs to ensure safe operation.

The method used to test an installation may inject a current into the system. This current must not cause danger to any person or equipment in contact with the installation, even if the circuit being tested is faulty. The test results must be compared with any relevant data, including the IEE Regulation tables, and the test procedures must be followed carefully and in the correct sequence, as indicated by Regulation 612.1. This ensures that the protective conductors are correctly connected and secure before the circuit is energized.

1.1. Visual Inspection

The aim of the visual inspection is to confirm that all equipment and accessories are undamaged and comply with the relevant British and European Standards, and also that the installation has been securely and correctly erected Regulation 611.3 gives a checklist for the initial visual inspection of an installation, including:

- Connection of conductors;
- Identification of conductors;
- Routing of cables in safe zones;
- Selection of conductors for current carrying capacity and volt drop;
- Connection of single-pole devices for protection or switching in phase conductors only;
- Correct connection of socket outlets, lamp holders, accessories and equipment;
- Presence of fi re barriers, suitable seals and protection against thermal effects;

- Methods of 'basic protection' against electric shock, including the insulation of live parts and placement of live parts out of reach by fitting appropriate barriers and enclosures;
- Methods of 'fault protection' against electric shock including the presence of earthing conductors for both protective bonding and supplementary bonding.
- Prevention of detrimental influences (e.g. Corrosion);
- Presence of appropriate devices for isolation and switching;
- Presence of under voltage protection devices;
- Choice and setting of protective devices;
- Labeling of circuits, fuses, switches and terminals;
- Selection of equipment and protective measures appropriate to external influences;
- Adequate access to switchgear and equipment;
- Presence of danger notices and other warning notices;
- Presence of diagrams, instructions and similar information;
- Appropriate erection method.

1.2. Approved Test Instruments

All test equipment must be chosen to comply with the relevant parts of BS EN 6155. The test instrument must also carry a calibration certificate, otherwise the recorded results may be void. Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier. This will maintain the accuracy of the instrument to an acceptable level, usually within 2% of the true value. Let us now look at the requirements of three often used test meters.

1.3. Continuity tester

To measure accurately the resistance of the conductors in an electrical installation we must use an instrument which is capable of producing an open circuit voltage of between 4 and 24V ac. or dc., and deliver a short-circuit current of not less than 200mA

(Regulation 612.2.1). The functions of continuity testing and insulation resistance testing are usually combined in one test instrument.

I. Insulation resistance tester

The test instrument must be capable of detecting insulation leakage between live conductors and between live conductors and earth. To do this and comply with Regulation 612.3 the test instrument must be capable of producing a test voltage of 250, 500 or 1000V and deliver an output current of not less than 1mA at its normal voltage.

II. Earth fault loop impedance tester

The test instrument must be capable of delivering fault currents as high as 25A for up to 40 ms using the supply voltage. During the test, the instrument does an Ohm's law calculation and displays the test result as a resistance reading.

III. Inspection Requirements

Verify that selected elements associated with the applicant's program for inspection, test control, and controls of M&TE (as identified in an approved inspection plan) are in accordance with the applicant's approved QA Plan.

Elements chosen for inspection may include three or more of the following:

Verify that inspection requirements and acceptance criteria are contained in the applicable design documents approved by the responsible design organization. Verify that inspection activities are documented and controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means.

- Verify that tests required to verify conformance of an item to specified requirements, and to demonstrate satisfactory performance for service, are planned and executed. Verify that the characteristics to be tested and test methods to be employed are specified. Verify that test results are documented and their conformances with acceptance criteria are evaluated.
- Verify that the applicant has established controls for tools, instruments, gauges, and other M&TE used for quality-affecting activities. Verify that M&TE is controlled, calibrated (at specified periods), and adjusted to maintain accuracy within necessary limits.
- Verify that the applicant has established the requirements to identify the status of inspection and test activities. Verify that the status is indicated either on the

items or in documents traceable to the items, where it is necessary to assure that required inspections and tests are performed, and to assure that items that have not passed the required inspections and tests are not inadvertently installed, used, or operated. Verify that the status is maintained through indicators (i.e., physical location and tags, markings, shop travelers, stamps, inspection records, computerized logs, or other suitable means). Verify that authority for application and removal of tags, markings, labels, and stamps is specified. Verify that status indicators provide for indicating the operating status of systems and components of the facility (i.e., tagging valves and switches) to prevent inadvertent operation.

1.4. Inspection Guidance

The inspector should refer to the applicant's approved QA Plan for specific requirements and commitments. Verify that the following inspection activities are documented and controlled by instructions, procedures, drawings, checklists, travelers, or other appropriate means:

a. Inspection Planning.

Verify that documented inspection planning includes the following:

1. Identification of each work operation where inspection is necessary to ensure quality;
2. Identification of documents that are used to perform the inspections;
3. Identification of the characteristics for inspection and the identification of when, during the work process, inspections are to be performed for those characteristics;
4. Identification of inspection or process-monitoring methods employed;
5. Sufficient information from the final inspection, to provide a conclusion regarding conformance of the item to specified requirements;
6. Identification of the functional-qualification level (category or class) of personnel performing inspections;
7. Identification of acceptance criteria;
8. Identification of sampling requirements;
9. Methods to record inspection results; and Selection and identification of the M&TE to be used to perform the inspection to ensure that the equipment is calibrated and is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

b. Selecting Inspection Personnel to Perform Inspections.

1. Determine that the individual who performs an inspection to verify conformance of an item to specified acceptance criteria is qualified to the requirements specified in the applicant's approved QA Plan.
2. Verify that inspections are performed by personnel other than those who performed or directly supervised the work being inspected. Verify that inspection personnel do not report directly to the immediate supervisor responsible for the work being inspected.

c. Inspection Hold Points.

1. If mandatory inspection hold points are used to control work, then verify that specific hold points are indicated in documents.
2. When applicable, verify that consent to waive hold points are documented and approved before to continuing work beyond the designated hold point.

d. In-Process Inspections and Monitoring.

1. If inspection of processed items is not practicable, then verify that indirect control is provided by the monitoring of processing methods, equipment, and personnel.
2. Verify that both inspection and process monitoring are conducted, when control is inadequate with only one method.
3. Verify that controls are established and documented for the coordination and sequencing of the work at established inspection points during successive stages of the process.

e. Final Inspection.

1. Verify that finished items are inspected for completeness, markings, calibration, adjustments, protection from damage, or other characteristics, as required to verify the quality and conformance of the item to specified requirements.
2. Verify that final inspections include a review of the results and resolution of nonconformance's identified by earlier inspections. If modifications, repairs, or replacements of items are performed subsequent to the final inspection, then verify that appropriate re-tests or re-inspections are performed.

f. Accepting Items.

Verify that the acceptance of an item is documented and approved by qualified and authorized personnel.

g. . Inspection Documentation.

Verify that inspection documentation includes the following:

1. The item inspected, date of inspection, the name of the inspector, or the inspector's unique identifier, who documented, evaluated, and determined acceptability;
2. The name of the data recorder, as applicable, and the type of observation or method of inspection;
3. The inspection criteria, sampling plan, or reference documents used to determine acceptance;
4. Results indicating acceptability of characteristics inspected;
5. M&TE used during the inspection, including the identification number and the most recent calibration date; and
6. Reference to information on actions taken in connection with nonconformance.

Verify that the following test control activities are conducted and documented in accordance with the applicant's approved QA Plan:

a. Test Planning.

Verify that test planning includes the following:

1. Identification of documents to be developed to control and perform tests;
2. Identification of items to be tested, test requirements, and acceptance limits, including required levels of precision and accuracy;
3. Identification of test methods to be employed and instructions for performing the test;
4. Identification of test prerequisites addressing, calibration for instrumentation, adequacy of test equipment and instrumentation, qualifications of personnel, condition of test equipment and the item to be tested, suitably controlled environmental conditions, and provisions for data acquisition;
5. Identification of mandatory hold points and methods to record data and results; and

6. Selection and identification of the M&TE to be used to perform the test to ensure that the equipment is of the proper type, range, accuracy, and tolerance to accomplish the intended function.

b. Performing Tests.

Verify that tests are performed in accordance with the applicant's QA procedures, and, as applicable, include the following:

1. Provisions for determining when a test is required, describing how tests are performed, and ensuring that testing is conducted by trained and appropriately qualified personnel.
2. Test objectives and provisions for ensuring that prerequisites for the given test have been met, adequate calibrated instrumentation is available and used, necessary monitoring is performed, and suitable environmental conditions are maintained.
3. Test requirements and acceptance criteria provided or approved by the organization responsible for the design of the item to be tested, unless otherwise designated.
4. Test requirements and acceptance criteria based on specified requirements contained in applicable design or other pertinent technical documents.
5. Potential sources of uncertainty and error.

c. Use of Other Testing Documents.

Other testing documents (e.g., American Society for Testing and Materials specifications, vendor manuals, or other related documents containing acceptance criteria) may be used instead of preparing special test procedures. If the applicant uses other documents, then verify that the information is incorporated directly into the approved test procedure, or incorporated by reference in the approved test procedure.

d. Tests Results.

Verify that test results are documented and their conformance with acceptance criteria evaluated by a qualified individual within the responsible organization, to ensure that the test requirements have been satisfied.

e. Test Documentation.

Verify that test documentation includes the following:

1. Item or work product tested, date of test, names of tester and data recorders, type of observation, and method of testing;
2. Test criteria or reference documents used to determine acceptance;
3. Results and acceptability of the test;
4. Actions taken in connection with any nonconformance's noted;
5. The individual evaluating the test results; and M&TE used during the test, including the identification number and the most recent calibration date.

f. Qualification of Test Personnel.

Verify that the individual who directs a test to verify conformance of an item to specified acceptance criteria is qualified in accordance with the applicant's approved QA Plan. Verify that tests are directed by personnel other than those who performed or directly supervised the work being tested. Verify that test directors do not report directly to the immediate supervisor responsible for the work being tested.

Self-Check 1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. List down initial visual inspection of an installation, includes:-(5%)

_____,_____

_____,_____

_____,_____

2. How to Verify final Inspection (4%)

_____,_____

_____,_____

_____,_____

. Answer the following question!

Note: Satisfactory rating 3 and 5 points Unsatisfactory below 3 and 5 points

You can ask you teacher for the copy of the correct answers.

Score = _____
Rating: _____

Answer Sheet

Name: _____ Date: _____

Information Sheet-2. Conduct appropriate functional test

2.1Testing of Medical devices

Visual inspection: is a relatively easy procedure to make sure that the medical equipment in use still conforms to the specifications as released by the manufacturer and has not suffered from any external damage and/or contamination.

These can include the following inspections:

A. Housing Enclosure – Look for damage, cracks etc.
B. Contamination – Look for obstruction of moving parts, connector pins etc.
C. Cabling (supply, Applied Parts etc) – Look for cuts, wrong connections etc
D. Fuse rating – check correct values after replacement
E. Markings and Labelling – check the integrity of safety markings
F. Integrity of mechanical parts – check for any obstructions

Earth bond Testing: it referred to as Ground bond Testing, tests the integrity of the low resistance connection between the earth conductor and any metal conductive parts, which may become live in case of a fault on Class I medical devices. Although many Class I medical devices are supplied with an Earth reference point, most if not all medical devices require multiple Earth bond tests to validate the connections of additional metal accessible parts on the enclosure.

Faults in the detachable power cord account for 80-90% of all Earthbond failures, as most moulded power cables are prone to stress when the cables are dropped.

For fixed installations (i.e. MRI or X-RAY equipment) a Point-to-Point continuity measurement can be made. The resistance is then measured between two probes, where one would be connected to the incoming Earth reference point and one probe placed on metal accessible parts of the medical installation.

Test limits are set at 0.1 ohm for fixed power cords and 0.2 ohm for equipment with a detachable power cord. The table below gives a full overview of the IEC 60601-1 test limits.

Prolonged use of testing at high currents can lead to a high probe temperature. Care should be taken to avoid touching the probe tip under these conditions.

1.1. Insulation Tests

IEC 60601-1 (second edition), clause 17, lays down specifications for electrical separation of parts of medical electrical equipment compliance to which is essentially verified by inspection and measurement of leakage currents. Further tests on insulation are detailed under clause 20, "dielectric strength". These tests use AC sources to test equipment that has been pre-conditioned to specified levels of humidity. The tests described in the standard are type tests and are not suitable for use as routine tests.

Satisfactory earth continuity and insulation test results indicate that it is safe to proceed to leakage current tests.

1.2. Single Fault Condition (SFC)

To maintain a Medical Device's high level of protection during its operational life, a number of design features are taken into account to maintain the integrity of the Device's electrical safety. This is done by introducing conditions that could occur under normal use (i.e. reversed mains supply or voltage on signal input/output terminals - SIP/SOP) and conditions that can occur under a single fault condition (SFC).

IEC 60601-1 specifies a number of single fault conditions (SFC) under its clause 8.1. For the purpose of this précis, the only highlighted SFC are the interrupted Earth connection (Open Earth) and interruption of any of the supply conductors (Open Neutral).

Where a single fault condition is not applied, the equipment is said to be in "normal condition" (NC). However, it is important to understand that even in this condition; the

performance of certain tests may compromise the means of protection against electric shock. For example, if earth leakage current is measured in normal condition, the impedance of the measuring device in series with the protective earth conductor means that there is no effective supplementary protection against electric shock.

IEC 60601-1 specifies that all leakage measurements should be carried out using normal and single fault conditions. A typical part of the electrical safety testing procedures is to perform the test as follows:

1. Normal Supply Voltage No (SFC)
2. Normal Supply Voltage Open Neutral
3. Normal Supply Voltage Open Earth
4. Reversed Supply Voltage No (SFC)
5. Reversed Supply Voltage Open Neutral
6. Reversed Supply Voltage Open Earth

In addition to these tests, some manufacturers might choose to include voltage on the signal input/ output terminals (i.e. communication ports such as USB or RS 232). As this test can be destructive, it is not commonly used other than during type testing of the medical electrical equipment.

1.3. Earth Leakage Test

The leakage current measuring device recommended by IEC 60601-1 loads the leakage current source with a resistive impedance of about 1 kΩ and has a half power point at about 1 kHz. The recommended measuring device was changed slightly in detail between the 1979 and 1989 editions of the standard but remained functionally very similar. The figure below shows the arrangements for the measuring device. The millivolt meter used should be true RMS reading and should have input impedance greater than 1 MΩ. In practice this is easily achievable with most good quality modern millimetres.

Many safety testers offer the opportunity to perform the test under single fault condition, neutral conductor open circuit. This arrangement normally gives a higher leakage current reading. One of the most significant changes with regard to electrical safety in the 2005 edition of IEC 60601-1 is an increase by a factor of 10 in the allowable earth leakage current to 5mA in normal condition and 10mA under single fault condition. The

rationale for this is that the earth leakage current is not, of itself, hazardous. Higher values of earth leakage currents, in line with local regulation and IEC 60364-7-710 (electrical supplies for medical locations), are allowed for permanently installed equipment connected to a dedicated supply circuit.

1.4. Enclosure Leakage Testing (Touch Current)

In general, Enclosure Leakage displays the current that would flow if a person came into contact with the housing (or any accessible part not intended for treatment or care) of the Medical Device. IEC 60601-1 specifies that the measurements are done under normal and reverse operation of the mains supply and single fault conditions Open Neutral circuit and Open Earth. The Enclosure Leakage Test is valid for both Class 1 and II equipment with Types B, BF and CF Applied Parts.

Many safety testers also allow the SFC's of interruption of live or neutral conductors to be selected. Points on class I equipment which are likely not to be protectively earthed may include front panel fascia's, handle assemblies etc. The term "enclosure leakage current" has been replaced in the new edition of the IEC 60601-1standard by the term "touch current", bringing it into line with IEC 60950-1 for information technology equipment. However, the limits for touch current are the same as the limits for enclosure leakage current under the second edition of the standard, at 0.1 mA in normal condition and 0.5 mA under single fault condition. In practice, if a piece of equipment has accessible conductive parts that are protectively earthed, then in order to meet the new requirements for touch current, the earth leakage current would need to meet the old limits. This is due to the fact that when the touch current is tested from a protectively earthed point with the equipment protective earth conductor disconnected, the value will be the same as that achieved for earth leakage current under normal condition. Hence, where higher earth leakage currents are recorded for equipment designed to the new standard, it is important to check the touch current under single fault condition, earth open circuit, from all accessible conductive parts.

1.5. Patient Leakage Current Testing

The Patient Leakage Current is the current flowing from the Applied Part via the patient to Earth or flowing from the patient via an Applied Part to Earth, which originates from an unintended voltage appearing on an external source. IEC 60601-1 specifies that the

measurements be done under normal and reverse operation of the mains supply and single fault conditions Open Neutral circuit and Open Earth.

Great care must be taken when performing patient leakage current measurements that equipment outputs are inactive. In particular, outputs of diathermy equipment and stimulators can be fatal and can damage test equipment.

1.6. The Patient Leakage F-Type Test (mains on applied parts)

The Patient Leakage F-Type Test (also known as mains on Applied Parts test) displays the current that would flow if a mains potential was applied to the Applied Part which was attached to a patient (i.e. a single fault condition). This test is applied only to type BF and CF equipment. This test involves applying a current limited mains potential (110% of mains input voltage) to the Applied Parts connections. Due to the requirements for IEC 60601-1 this test current can be in excess of 5mA under short circuit conditions and as such is hazardous to the user. Caution should be taken when conducting this test.

1.7. Patient Auxiliary Current

The Patient Auxiliary Current displays the leakage current that would flow between Applied Parts under normal and fault conditions. For these tests, current is measured between a single part of the Applied Part and all other Applied Parts connected together. This test should be repeated until all combinations have been tested. This is also referred to as Applied Part to All.

Self-Check 2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. How the electrical safety testing procedures is perform(5%)

_____,_____

_____,_____

_____,_____

_____,_____

. Answer the following question!

Note: Satisfactory rating 3 and points Unsatisfactory below 3 and 5 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet 3. Clean and clear work site

3.Clean and clear work site

3.1. Practice good housekeeping in the workplace

Workplace Housekeeping Program

The center advises training employees on how to safely work with the products around them. Also, integrate housekeeping responsibilities into jobs by having workers clean up as they go during shifts by removing waste and unused materials and inspecting their work area to ensure cleanup was properly completed.

Additional tips include:

- Ensure all spills are immediately cleaned up. Replace worn, ripped and damaged flooring and place anti-slip flooring in areas that cannot continually be cleaned, such as an entrance.
- Maintain clean light fixtures to improve lighting efficiency.
- Keep aisles and stairways clear. Consider installing warning signs and mirrors to help improve sight lines in blind corners.
- Regularly inspect, clean and repair all tools.
- Do not use damaged tools.

Advantages to Maintaining a Clean Workplace

There are many ‘hidden’ advantages to maintaining a clean workspace:

- There’s a direct correlation between a clean work environment and improved employee health. A clean environment can help reduce worker sick days.

- A regular cleaning program preserves and protects building assets such as carpets, floors, tile surfaces, equipment. It prevents excessive wear and extends life spans.
- A sparkling workplace can be an excellent marketing tool, whether you're trying to impress prospective clients, lease space or sell the building.
- A clean, healthy building plays extremely well with occupants, creating a welcoming atmosphere, often subconsciously encouraging hard work and collective effort.
- The appearance is one of the major elements that separates one building from another and brings added value.

1.1. Hazard Assessment

Certain areas of the building will require different types of cleaning due to differences in the types of hazards. For example, areas requiring differential housekeeping attention include:

- Entryways and lobbies
- Bathrooms
- Hallways and corridors
- Kitchen and cafeteria
- Offices
- Warehouse

1.2. Housekeeping Areas—Safe Work Practices

Supervisors and workers will implement the following safe work practices for housekeeping in all areas of the facility.

1.3. All Working Surfaces

- Keep all walking and working surfaces clean, sanitary, and orderly.
- Keep work surfaces dry.
- Clean up small spills immediately; report large spills to a supervisor.
- Ensure that all walking and working surfaces and passageways are free from protruding nails, splinters, holes, or loose boards.

- **Elevated Surfaces**
  - ✓ Pile, stack, or rack material on elevated surfaces in a manner that will prevent the material from tipping, falling, collapsing, rolling, or spreading.

- ✓ Use dock boards or bridge plates when transferring materials between docks and trucks or railcars.

.

- **Lighting**

✓ Ensure that all halls and stairwells are well lighted to help reduce accidents and promote security. Replace light bulbs and/or fixtures as necessary to maintain adequate lighting at all times.

- **Fire and Explosion Prevention**

✓ Flammable and combustible materials and residues will be controlled so that they do not cause or contribute to a fire emergency.

- **Maintenance of Ignition Sources**
  - ✓ Equipment and systems installed on heat- or ignition-producing equipment and processes will be maintained to prevent the accidental ignition of flammable and combustible materials.
- ***Dry Combustibles***
  - ✓ Keep combustibles such as paper, cardboard, wooden pallets, or rags in designated locations away from ignition sources. The accumulation of such material provides a place for a fire to start and spread quickly.
- ***Extension Cords***
    - Electric extension cords will be inspected before each use and kept in good condition.
    - Employees will not yank cords from electrical outlets.
    - Tools and equipment that require grounding will be of the three-wire grounded-connection type.
    - Never use extension cords to replace permanent wiring.
    - If an extension cord is used for temporary wiring, it must be listed by Underwriters Laboratories or another recognized testing laboratory.
    - Avoid kinking or excessive bending of the cord; broken strands may pierce the insulated covering and become a shock or short-circuit hazard.

Flammable and Combustible Liquid Storage

- ***General Safe Work Practices***

- ✓ No open flames, smoking, sparks, or welding will be allowed in storage areas with flammable liquids.
- ✓ Electrical equipment must be explosion-proof if flammable or combustible liquid will be stored near such equipment.
- ✓ Keep flammable and combustible liquids away from direct sunlight and stored in a cool, dry place.
- ✓ The storage area must be well ventilated to prevent vapors from building up; the vents should be from floor to ceiling.
- ✓ Store oxidizers and other incompatible materials away from flammable and combustible liquids to prevent a dangerous reaction.
- ✓ Use secondary containment methods to make sure any spills are contained.
- ✓ Return flammable and combustible liquids to their storage location immediately after use.

- ***Containers***
  - ✓ Store flammable and combustible liquids in approved fire-resistant containers with self-closing lids. Ensure that such containers are grounded and bonded during any transfer of flammable or combustible liquids between containers. These containers prevent sparks and other ignition sources from igniting the liquids stored in them. Keep the containers closed when not in use.
- **Used rags.**
  - ✓ Put rags soaked with flammable or combustible liquids in approved, closed containers. The containers must be kept closed to prevent vapor buildup.
- ***Reactive Materials***
  - ✓ Do not store reactive materials near one another. Reactive materials, when mixed, often create an exothermic reaction, which produces heat and could cause these materials to spontaneously combust.

Electrical and Hot Equipment

- Keep combustible materials, dust, and grease away from electrical equipment and hot machinery.

- Maintain a clear access to electrical panels at all times so that they can be opened quickly in case of an emergency that requires the power to a machine or the building to be shut down.

Combustible Dust

Combustible dusts that accumulate on surfaces can cause a deflagration, other fires, or an explosion. Combustible dusts are often either organic or metal dusts that are finely ground into very small particles, fibers, fines, chips, chunks, flakes, or a small mixture of these. These dusts include, but are not limited to:

- Metal dust, such as aluminum and magnesium
- Wood dust
- Coal and other carbon dusts
- Plastic dust and additives
- Bio solids
- Other organic dust, such as sugar, flour, paper, soap, and dried blood
- Certain textile materials

- ***Criteria for Dust Cleanup***

Immediate cleaning and collection of accumulated combustible dust is warranted whenever a layer of combustible dust 1/32-inch thickness (i.e., approximately the thickness of a typical paper clip) accumulates over a surface area of at least 5 percent of the floor area of the facility or any given room.

The 5 percent factor will not be used if the floor area exceeds 20,000 square feet (sq ft), in which case a 1,000 sq ft layer of dust is the upper limit. Accumulations on overhead beams, joists, ducts, the tops of equipment, and other surfaces should be included when determining the dust coverage area. Vertical surfaces will be included if the dust is adhering to them. Likely areas of dust accumulations within a plant are:

- ✓ Structural members
- ✓ Conduit and pipe racks
- ✓ Cable trays
- ✓ Floors
- ✓ Above the ceiling
- ✓ On and around equipment (leaks around dust collectors and ductwork)

- ***Procedures for Dust Cleanup***

Routinely remove accumulations of combustible dust from elevated surfaces, including the overhead structure of buildings. Accumulations will be removed and collected in dust collectors.

- ***Hot Work near Dust Collection Points***

The Administrator or designee will ensure that approved hot work permits are issued for any hot work in areas where hazardous levels of dust accumulations may occur. In addition, anyone who performs combustible dust collection operations near hot work on and around collection points and ductwork must receive written approval to perform such work from the issuer of the hot work permit. Dust collection operations will not be conducted while hot work operations are in progress.

- **Waste Recycling and Disposal**

The Administrator or designee will ensure that the following waste recycling and disposal procedures are implemented in all work areas where such waste is generated:

- ✓ Scrap materials will be collected and sorted for recycling or disposal.
- ✓ Scrap containers will be placed near areas where the waste is produced to encourage orderly waste recycling or disposal.
- ✓ All waste receptacles will be clearly labeled (e.g., recyclable glass, plastic, metal, toxic, flammable).
- ✓ All waste containers will be emptied.
- ✓ Covered metal waste can will be provided for oily or paint-soaked waste.

Hazardous Chemical Spill Control

The Administrator or designee will implement procedures for the cleanup of large and small hazardous chemical spills at the facility. Large spills will be managed according to the facilities

Spill Prevention Safety Plan.

Spill Prevention

Regularly cleaning and maintaining machines and equipment are ways to do this. Others are to use drip pans and guards where possible spills might occur.

Small Spills

The following procedure will be followed by all employees when a small chemical spill less than has occurred:

1. Notify *[insert name]*.
2. If toxic fumes are present, secure the area (with caution tape or cones) to prevent other personnel from entering.
3. Deal with the spill in accordance with the instructions described in the safety data sheet (SDS).
4. Small spills must be handled in a safe manner while wearing the proper PPE.
5. Use absorbent material to wipe up greasy, oily, or other liquid spills.
6. Absorbents must be disposed of properly and safely.

1.4. Electrical Parts and Equipment

Employees will not perform housekeeping duties near live electrical parts where there is a possibility of contact, unless adequate safeguards such as insulating equipment or barriers are provided. See the Electrical Safety Plan for information about safe work distances and other electrical hazard control procedures. Electrical equipment will be kept free of dust, debris, and grease.

- **Cleaning Materials**

Electrically conductive cleaning materials, including conductive solids such as steel wool, metalized cloth, and silicon carbide, as well as conductive liquid solutions, will not be used near energized parts unless written procedures authorized by the Administrator or designee that will prevent electrical contact are followed.

- **General Storage**

The Administrator or designee will ensure that the following general material storage procedures are implemented:

- ✓ Store or stack materials to allow a clear space of 3 feet or more under water sprinkler heads.
- ✓ Stack cartons and drums on a firm foundation and cross-tie them where necessary to reduce the chance of their movement.
- ✓ Do not allow stored materials to obstruct aisles, stairs, exits, fire equipment, emergency eyewash fountains, emergency showers, or first aid stations.
- ✓ All storage areas will be clearly marked.

Machines and Tools

Machines

- Keep the area around machines clear of combustibles, slip and trip hazards, or any other debris.
- Inspect machines before use.
- Ensure that all guards are in place and operating properly.
- Follow lockout/tag out procedures when servicing or repairing a machine.
- When done using the machine put away tools and clean up both the machine and the work area.

Hand and Power Tools

- Store blades and sharp tools carefully so that they do not create a hazard when not in use.
- Store new blades for band saws, circular saws, or utility knives in labeled boxes so someone doesn't accidentally stick his or her hands inside and get cut.
- When it's time to discard an old blade, cover the sharp edge with tape or cardboard and discard the blade directly into a metal trash container or Dumpster.
- Keep blades on utility knives sheathed or retracted when not in use.

1.5. **PPE**

The Administrator or designee will ensure the appropriate PPE is provided to and worn by employees performing housekeeping activities and that the PPE is in good condition. PPE will not be used as a substitute for engineering, safe work practice, or administrative controls for preventing exposure to recognized physical or chemical hazards.

PPE for housekeeping operations include:

- Eye protection
- Gloves
- Proper shoes
- Dust masks
- Other items such as protective clothing, respirators, and hearing protection, depending on the hazards

Employees involved in housekeeping activities will implement the following PPE use and care procedures:

- Inspect PPE before each use, checking for signs of wear or damage.
- Keep PPE clean.
- Store PPE properly according to instructions on labels or received during training to prevent damage or contamination from dirt or chemicals.
- Replace PPE when it is worn out, damaged, or no loner provides the protection that is required.

When performing housekeeping tasks, employees will select the right equipment for the job, including the right PPE. Employees must consult with a supervisor concerning appropriate PPE when starting a new job or housekeeping task.

Inspections

Programs related to housekeeping will be regularly monitored to ensure a high standard of sanitation and safety in all work areas, as well as to identify deficiencies. The Administrator or designee(s) will conduct regular inspections of work areas to monitor hazards and ensure that housekeeping safe work practices are implemented.

The Administrator or designee(s) will develop housekeeping inspection schedules and checklists for each work area with specific hazards or work processes that differ from those found in the facility as a whole.

Frequency of Inspections

The frequency of inspections for each work area will be determined by identification of hazards and hazard control recommendations from hazard assessments, deficiencies identified in previous inspections, frequency of changes in work processes, and any other factors that may affect compliance with housekeeping requirements and policies.

At a minimum, inspections of all work areas will be conducted *[insert minimum frequency]*. Surprise inspections may be conducted at any time.

Inspection Documentation

Copies of inspection checklists or reports will be kept at *[insert location]*. Each report will be maintained for *[insert period of time]* after the date of the inspection.

Emergencies

The Administrator or designee will ensure that:

- All evacuation routes are clearly marked and unobstructed.

- Access to fire extinguishers and other emergency equipment is unobstructed.
- All emergency-related signs, placards, posters, notices, and markings are clearly visible and legible at all times.
- All used emergency and fire-fighting equipment is replaced.

Post-emergency cleanup operations will be conducted by personnel trained and authorized to perform specific cleanup tasks.

Training

[Manager XYZ] will provide housekeeping training to all employees at the time of hire and as needed thereafter.

Supervisors will provide safety meetings or talks to employees as a group every *[insert time & date]* and to individual employees who fail to follow safe procedures.

Training Records

Training will be documented with employee sign-in sheets, date of training, and the training session agenda.

Self-Check 3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Chose the correct answer

1. A relatively easy procedure to make sure that the medical equipment in use still conforms to the specifications as released by the manufacturer

   A. Visual inspection B. Enclosure Leakage C. Patient Auxiliary Current D. All

2. Earth bond Testing: it referred to as Ground bond Testing, tests the integrity of the low resistance connection between the earth conductor

   A. Earth bond Testing B. Enclosure Leakage C. Patient Auxiliary Current D. All

3. Displays the leakage current that would flow between Applied Parts under normal and fault conditions.

   A. Visual inspection B. Enclosure Leakage C. Patient Auxiliary Current D. All

4. Displays the current that would flow if a person came into contact with the housing of the Medical Device.

   A. Visual inspection B. Enclosure Leakage C. Earth bond Testing D. All

5. Which one of the following is not included in visual inspections:

   A. Housing Enclosure – Look for damage, cracks etc.

   B. Fuse rating – check correct values after replacementMarkings and Labelling – check the integrity of safety marking

. Answer the following question!

Note: Satisfactory rating 6 and 10 points Unsatisfactory below 6 and 10 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____

Rating: _____

Name: _____ Date: _____

Information Sheet-4. Record test results

4.1Testing of Medical devices

Safe working procedures when testing

Whether you are carrying out the test procedure

(i) As a part of a new installation

(ii) Upon the completion of an extension to an existing installation

(iii) Because you are trying to discover the cause of a fault on an installation or

(iv) Because you are carrying out a periodic test and inspection of a building, you must always be aware of your safety, the safety of others using the building and the possible damage which your testing might cause to other systems in the building.

For your own safety:

A. Always use ‘approved’ test instruments and probes.

B. Ensure that the test instrument carries a valid calibration certificate otherwise the results may be invalid.

C. Secure all isolation devices in the ‘off’ position.

D. Put up warning notices so that other workers will know what is happening.

E. Notify everyone in the building that testing is about to start and for approximately how long it will continue.

F. Obtain a ‘permit-to-work’ if this is relevant.

G. Obtain approval to have systems shut down which might be damaged by your testing activities. For example, computer systems may ‘crash’ when supplies are

switched off. Ventilation and fume extraction systems will stop working when you disconnect the supplies.

1.1. Requirements for safe working procedures

The following five safe working procedures must be applied before undertaking the fault diagnosis.

1. The circuits must be isolated using a 'safe isolation procedure',
2. All test equipment must be 'approved' and connected to the test circuits by recommended test probes as described by the Health and Safety Executive (HSE) Guidance
3. Isolation devices must be 'secured' in the 'off' position as shown in
4. Warning notices must be posted.
5. All relevant safety and functional tests must be completed before restoring the supply.

1.2. Record-keeping

In order for an eye care unit to manage its equipment effectively, it needs good maintenance and repair records. It is very difficult to manage the unknown!

A central maintenance and repair record will help you to keep track of the maintenance and repair work done. Ideally, this system should correspond to the eye unit's equipment inventory (mentioned on page 34); this means that you will have maintenance and repair records for each of the items listed in the inventory.

1.3. Record-keeping for maintenance

The preventative maintenance schedule for users can be accompanied by a weekly or monthly 'tick sheet' near the item of equipment, with a space for each day so that users can date and sign it, thereby showing that they have carried out the required tasks. This may include a space for users to indicate what spare parts, such as bulbs, were used. On a regular basis, the list of spare parts used should be noted in the central maintenance and repair record so that more spare parts can be ordered.

The central maintenance and repair record can be used to keep track of all other maintenance, including maintenance done by the in-house team, by vendors, or by service agents. The information captured should include the date, the equipment reference number, what was done, who did the work, and when next maintenance is due.

Self-Check 4	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I Fill the black space

1. **What is Record-keeping of maintenance?** (5%)

_____,_____
_____,_____
_____,_____
_____,_____

. Answer the following question!

Note: Satisfactory rating 5 and 9 points Unsatisfactory below 5 and 9 points

You can ask you teacher for the copy of the correct answers.

Answer Sheet

Score = _____
Rating: _____

Name: _____ Date: _____

Information Sheet-5. Record test results

5. Report test results

1.1. Technical Report Writing

Technical report today deals with an important aspect of every activity. In any industry and business today, everybody is expected to write a technical report on what he/she performed because it is in the main means of communication between department peoples and professionals.

In technical report, people express what they found, performed, and analyzed the problem they solved, the procedure and material used, the status of their performance, summaries of work and some recommendations. Thus, technical report writing is a process of producing technical reports, which comprises of the above components.

Anybody who produces technical report should know how to communicate with people to get reliable data, interpret data and analyze data, it is expected to know what medium of communication (oral, observation, letter, etc…) used to exchange data, how to document this data and generate the final report about the occurrence. So technical report writing is a practical repetitive activity of employees/students as part of jobs.

1.2. Purpose of technical report writing

Technical report writing has three basic purposes:

- To inform (receive and transfer data, activities done, procedures used, result of work)
- To instruct (directions to use equipment and for performing duties, provide technical support, descriptions…. etc)

- To perused (to tell reason why does follow rules/procedures, convince work to be done, to inform bottlenecks of the process).

1.3. Types of Report

There are many cases to classify technical report such as subject matter, functions, frequency of issuance, type and formality of forms, length…but, traditionally there are two descriptive categories

1. Informational report and
2. Analytic report

1. The Informational Report

Presents information without criticism evolution and recommendation It provides

- Detailed account of activities
- No attempt to provide solution to problems
- Information on present and past events

Example inventory report, sales report, progress report

2. The Analytic Report

It is a report goes beyond informational reports since it presents an analysis and interpretation of the fault in addition to the facts. The conclusion and recommendations are the most important and interesting parts of the report. The analytical report serves as bases for the solution of an immediate problems or a guide to future happenings.

It is valuable and commonly used instruments for all types of activities to report by applying different techniques

1.4. Procedures of Report Writing

Report writing is reconstruction of in written form of purpose full analysis of a problem. Report writing goes through 4 steps of doing

1. Preliminary analysis and planning
2. Gathering of data [investigating the problem] situations
3. Organizing data and
4. Develop report

Self-Check 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:.

Say true or false

_____1. To inform (receive and transfer data, activities done, procedures used, result of work) is not basic purposes technical report writing

_____ 2. To instruct (directions to use equipment and for performing duties, provide technical support, descriptions…. etc) basic purposes technical report writing

_____ 3. The analytic report is a report goes beyond informational reports since it presents an analysis and interpretation of the fault in addition to the facts

_____ 4. Presents information with criticism evolution and recommendation provides detailed account of activities

_____ 5. Presents information without criticism evolution and recommendation provides Information on present and past events

. Answer the following question!

Note: Satisfactory rating 3and 5 points Unsatisfactory below 3 and 5 points

You can ask you teacher for the copy of the correct answers.

Score = _____
Rating: _____

Answer Sheet

Name: _____ Date: _____

Operation Sheet 1	**Inspecting and testing the repaired BMECS**

1.1. **Techniques for Inspect & test the repaired BMECS:**

Step 1- inspect to ensure that the testing conducted on the device conforms to the manufacturer's instruction/manual.

Step 2- clean and clear of all debris and left in safe condition in accordance with company procedures

Step 3- Test and record control devices history result on cards

Step 4- Report and complete according to company requirements.

LAP Test Method	**Practical Demonstration**
LAP Test Title/Activity 1	**Clean up work area**

Name: _____ Date: _____

Time started: _____ Time finished:

_____

Instructions:

Task 1. You are required to perform housekeeping on your workshop:

a. You will be given the necessary tools

b. Return all maintenance tools and equipment's

c. Clean all tools, materials and equipment's

d. You are required to re-arrange all chairs, etc…

e. You are required to wear PPE

Task 2. Request your teacher for evaluation and feedback

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Answer Key for self-check

Module Title: Maintaining and Repairing Biomedical Equipment Control Systems

LO #1-Plan and prepare for maintenance/ repair

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Self-Check 1	**Written Test**

I. Choose the best answer (each 1point)

1. C.

2. B

3.

Self-Check 2	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 1point)

1. A

2. B

3. D

Self-Check 3	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 1point)

1. A

2. C

3. D

4. A

5. D

6. B

7. C

8. D

9.

10.

Self-Check 4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 1point)

1. A

2. B

3. B

4. D

5. C

6. B

7. C

8. A

9.

10.

II Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

1. What is microprocessor?

- **microprocessor** is a computer processor which incorporates the functions of a computer's central processing unit (CPU) on a single integrated circuit (IC), or at most a few integrated circuits.
- The microprocessor is a multipurpose, clock driven, register based, digital-integrated circuit which accepts binary data as input, processes it according to instructions stored in its memory, and provides results as output.
- Microprocessors contain both combinational logic and sequential digital logic. Microprocessors operate on numbers and symbols represented in the binary numeral system.

2. The difference between combinational circuit and sequential circuit?

- **combinational circuit:** the simple time independent logic circuits that are implemented using Boolean circuits whose output logic value depends only on the input logic values can be called as combinational logic circuits.
- **sequential circuit**: the simple logic circuits whose output logic value depends on the input logic values and also on the stored information is called as sequential logic circuits.

3. List all the PLC hardware component?

- Central Processing Unit (CPU)
- Memory
- Input modules
- Output modules and
- Power supply.

4.The two basic forms of representation pneumatic system?

- Signal-flow representation
- Energy flow representation

5.List Main types Switch elements?

- Key-operated Switch
- Actuating Switch

Self-Check 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 1point)

1. A

2. C

3. C

4. B

5. D

LO #2-Maintain Biomedical Equipment Control Systems

Self-Check -1	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. B

2. D

3. D

Self-Check -2	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. B

2. B

3. C

4. A

5. D

Part II fill the blank space

2. **List down Types of Control System (2%**)

- Open Loop Control System
- Closed-Loop Control System

3. **Mention Advantage and Disadvantage of Close loop control system (5%)**

- Advantages:
  - ✓ High accuracy
- Disadvantages
  - ✓ Complicated and costly.
  - ✓ The system has a tendency to oscillate.

Self-Check 3	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. List down the electrical installation must be regularly inspected and tested by electricians . (5%)

- test for earth leakage
- test for circuit continuity
- test for loose connections
- perform insulation tests
- test switch leakages
- test for power
- check for the correct rating
- check whether wiring regulations were followed during installation.

2. Mentions To guarantee safety, they should perform a variety of tests on each piece of equipment depending on its Class and Type (5%)

- self-checks
- supply voltage check
- insulation resistance test
- earth bonding test
- earth leakage current test
- enclosure leakage current test
- patient leakage current test
- patient auxiliary current test mains voltage on the applied part test.

Self-Check 4	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. List down Risk Management and Mitigation measures will be applied to reduce the

- During the operation phase of the Project, Project components will be inspected periodically and repaired as required.

- Safe operating procedures will be established for all work activities, both during the construction and operation phases of the Project.
- NB Power's safety and environmental policies will be followed.
- Proper signage and public warning will be installed around project land-based components/facilities (e.g., "High Voltage").
- Access to the work site during construction and energizing activities will be limited to NB Power and their consultants and required contractor crews.

2. What is On-Site Hazardous Material Spill? (3%)

- The storage of liquid hazardous materials within buildings, in secure Contained areas;
- the provision of impermeable containment berms (or other forms of secondary containment);
- placement of protective barriers as appropriate;
- sitting of such facilities in locations that represent a relatively low risk and afford an opportunity for containment during emergency response;
- provision of alarms on secondary containment measures;
- careful implementation of fuel transfer operations; and
- Provision of an emergency response plan for the immediate isolation and clean-up of a release.

LO #3-Repair Biomedical Equipment Control Systems

Self-Check -1	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. D

2. C

3. D

Self-Check 2	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II Fill the black space

1. List down When a circuit board has been found to be faulty, component-level troubleshooting should be done (4%)

- Detailed signal tracing
- Voltage and resistance measurements
- Use of the equipment schematic showing interconnection between the individual components.

2. List down Principle of troubleshooting (6%)

- Systematic approach to locating the cause of a fault in an electronic circuit or
- Determining which part of a system is responsible for a problem
- A logical way of testing hardware or software in order to determine how to fix a problem

Self-Check 3	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

II Fill the black space

1. What is the difference Manual and automatic Calibration (5%)

1. What is the difference Manual and automatic Calibration (5%)

- **Manual calibration** : depressurizing the system, and turning the screw, if necessary, to ensure t**hat the needle reads zero,** fully pressurizing the system and ensuring that the needle reads maximum, with**in acceptable tolerances,** replacing the gauge if the error in the calibration process is beyond tolerance, as this may indicate signs of failure such as corrosion or material fatigue.
- **Automatic calibration**: which is a device that consists of a control unit housing the electronics that drive the system, a pressure intensifier used to compress a gas such as Nitrogen, a pressure transducer used to detect desired levels in a hydraulic accumulator, and accessories such as liquid traps and gauge fittings.

2. List Down a number of stages in the process of calibrating an analytical instrument.

- Plan the experiments;

- Make measurements;
- Plot the results;
- Carry out statistical (regression) analysis on the data to obtain the calibration function;
- Evaluate the results of the regression analysis;
- Use the calibration function to estimate values for test samples;
- Estimate the uncertainty associated with the values obtained for test samples.

Self-Check 4	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part II Fill the black space

1. . What is Unplanned events?
    - Unplanned events are accidents or upset events or conditions that are not planned as a part of routine Project activities during any Project phase. Even with the planning and application of mitigation, accidents, malfunctions, and unplanned events could occur during any phase of the Project.

2. The accidents, malfunctions, and unplanned events that have been selected based on experience and professional judgment are
    - Worker accident: worker accidents may occur during either construction or operation, and may result in harm, injury, or death to one or more Project workers;
    - Fire: consists of a fire in a Project component. The focus is on the consequence, and not the mechanism by which it occurs;
    - Electrical Hazardous materials spill: spills of fuel, petroleum products, and/or other chemicals used on site or in Project components.

Self-Check -5	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. D

2. A

3. D

4. B

5. D

LO #4-Inspect and test the repaired Biomedical Equipment Control Systems

Self-Check 1	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part I Fill the black space

1. List down initial visual inspection of an installation, includes:-

- Connection of conductors
- Identification of conductors
- Routing of cables in safe zones
- Selection of conductors for current carrying capacity and volt drop
- Connection of single-pole devices for protection or switching in phase conductors only
- Correct connection of socket outlets, lamp holders, accessories and equipment

1. How to Verify final Inspection

- Verify that finished items are inspected for completeness, markings, calibration, adjustments, protection from damage, or other characteristics, as required to verify the quality and conformance of the item to specified requirements.
- Verify that final inspections include a review of the results and resolution of nonconformance's identified by earlier inspections. If modifications, repairs, or replacements of items are performed subsequent to the final inspection

Self-Check 2	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part I Fill the black space

1. How the electrical safety testing procedures is perform

- Normal Supply Voltage No (SFC)
- Normal Supply Voltage Open Neutral
- Normal Supply Voltage Open Earth
- Reversed Supply Voltage No (SFC)
- Reversed Supply Voltage Open Neutral
- Reversed Supply Voltage Open Earth

Self-Check 3	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I. Choose the best answer (each 2 point)

1. A

2. A.

3. C.

4. B

5. B

Self-Check 4	**Written Test**

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

I Fill the black space

1. What is Record-keeping of maintenance?

- The preventative maintenance schedule for users can be accompanied by a weekly or monthly ‘tick sheet’ near the item of equipment, with a space for each day so that users can date and sign it, thereby showing that they

have carried out the required tasks. This may include a space for users to indicate what spare parts, such as bulbs, were used.

Self-Check 5	Written Test

Directions: Answer all the questions listed below. Use the Answer sheet provided in the next page:

Part I Say true or false

1. **False**
2. **True**
3. **True**
4. **False**
5. **True**