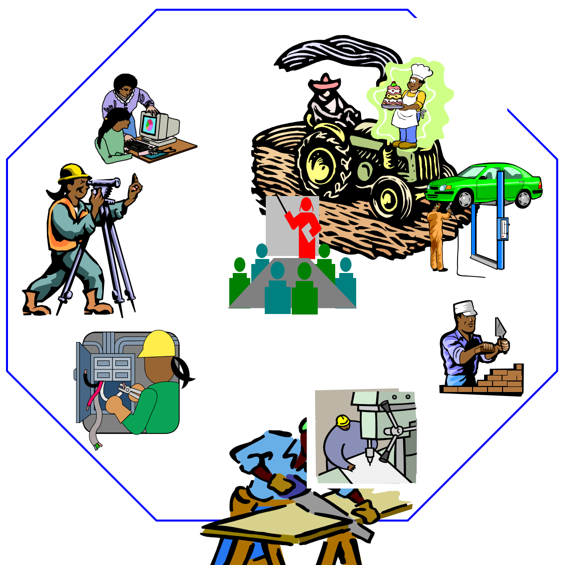
Pe

rforming Installation and Programming of Programmable logic control

Based on May, 2011 Version 2 OS and Dec, 2020 Version2 Curriculum



Module Title: Performing Installation and Programming of Programmable Logic Controller (PLC) System

LG Code: EEL ICS3 M08 LO (1-4) LG (26-29)

TTLM Code: EEL ICS3 TTLM 1220 v1

Dec. 2020

Bishoftu, Ethiopia

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

- Observing OH& S policies and procedures
- Reading and interpreting work instruction
- Selecting tools and testing devices
- Checking for correct operation and safety
- obtaining materials and components necessary to complete the work

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:

- Observe OH& S policies and procedures
- Read and interpret work instruction
- Select tools and test devices
- Check for correct operation and safety
- obtain materials and components necessary to complete the work

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).

Information Sheet 1- Observing OH& S policies and procedures

Plan and prepare for installation

- Observe Occupational Health and Safety policies and procedures in planning for installation activity in accordance with requirements
- Familiarize with computer hardware, software component and other peripherals in accordance with established procedures on correct operation and safety policies
- Consult appropriate/ technical personnel to ensure that work is coordinated with others who are involved in the activity
- Obtain materials necessary to complete the work in accordance with established procedures
- Check the materials received against job requirements

Observing OH& S policies and procedures

Occupational Health and Safety (OHS) Policy An instrumentation and control servicing (ICS) trainees should know how to behave when working in the instrumentation laboratory, as well as implement a safe way of accomplishing every task. Safety practices should be learned early and always adheres in working with any electrical and electronic device, including programmable logic controller, personal computers and its peripherals.

This is for your protection as well as to the people working with you, and for the devices that you are using. The basis for this process begins with Occupational Health and Safety Policies.

Occupational safety and health (OSH) is a planned system of working to prevent illness and injury where you work by recognizing and identifying hazards and risks. Health and safety procedure is the responsibility of all persons in the computer and technology industries. You must identify the hazards where you are working and decide how dangerous they are. Eliminate the hazard or modify the risk that it presents.

Occupational health and safety standards procedure

1. Identify the hazard
2. Clear the area close to the hazard
3. Partition the hazard off or clearly identify the area to protect other people from harm
4. If the hazard is easily and safely cleared, then do so

If not…

1. Report the hazard to the appropriate person (such as teacher in charge, principal etc.) to obtain assistance
2. Following clearing of the hazard fill out the correct documentation to assist in identifying improved practice to reduce further incidence of hazards.

All hazards must be reported using Accidental Report form. This enables us to track the kinds of hazards we have in our workplace, and take action where necessary to make it safer for all student and clients.

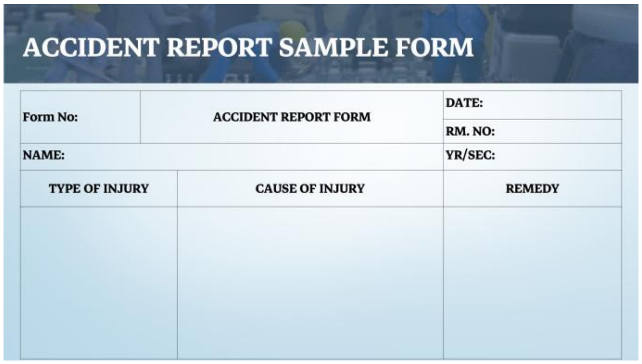
Accident reports

Forms are used to give specific details with regards to the accidents happened in the laboratory during experiments.

Accident reports contain the following details:

- Name of the person injured
- Date and time of the accident
- Type of injury
- First aid given

- Action taken to prevent further accidents



ACCIDENT REPORT SAMPLE FORM

Form No:	ACCIDENT REPORT FORM	DATE:
		RM. NO:
NAME:		YR/SEC:
TYPE OF INJURY	CAUSE OF INJURY	REMEDY

Fig 1 Accidents report sample form

A national framework for occupational safety and health management systems

National policy

A competent institution or institutions should be nominated, as appropriate, to formulate, implement and periodically review a coherent national policy for the establishment and promotion of OSH management systems in organizations. This should be done in consultation with the most representative organizations of employers and workers, and with other bodies as appropriate.

The national policy on OSH management systems should establish general principles and procedures to:

- promote the implementation and integration of OSH management systems as part
- of the overall management of an organization;
- facilitate and improve voluntary arrangements for the systematic identification, planning, implementation and improvement of OSH activities at national and organization levels;
- promote the participation of workers and their representatives at organization level;
- implement continual improvement while avoiding unnecessary bureaucracy, administration and costs;

- promote collaborative and support arrangements for OSH management systems at the organization level by labour inspectorates, occupational safety and health services and other services, and channel their activities into a consistent framework for OSH management;
- evaluate the effectiveness of the national policy and framework at appropriate intervals;
- evaluate and publicize the effectiveness of OSH management systems and practice by suitable means; and
- ensure that the same level of safety and health requirements applies to contractors and their workers as to the workers, including temporary workers, employed directly by the organization.

With a view to ensuring the coherence of the national policy and of arrangements for its implementation, the competent institution should establish a national framework for OSH management systems to:

- identify and establish the respective functions and responsibilities of the various institutions called upon to implement the national policy, and make appropriate arrangements to ensure the necessary coordination between them;
- publish and periodically review national guidelines on the voluntary application and systematic implementation of OSH management systems in organizations; establish criteria, as appropriate, for the designation and respective duties of the institutions responsible for the preparation and promotion of tailored guidelines on OSH management systems; and
- ensure that guidance is available to employers, workers and their representatives to take advantage of the national policy.

The competent institution should make arrangements and provide technically sound guidance to labour inspectorates, OSH services and other public or private services, agencies and institutions dealing with OSH, including health-care providers, to encourage and help organizations to implement OSH management systems.

1.1.1. Ethiopian Building Code Standards (EBCS)

The Proclamation to define the powers and duties of the Central and Regional Executive Organs of the Transitional Government of Ethiopia No. 41/1993 empowers the Ministry of Works and Urban Development to prepare the Country's Building Code, issue Standards for design and construction works, and follow up and supervise the implementation of same. In exercise of these powers and in discharge of its responsibility, the Ministry is issuing a series of Building Code Standards of general application. The purpose of these standards is to serve as nationally recognized documents, the application of which is deemed to ensure compliance of buildings with the minimum requirements for design, construction and quality of materials set down by the National Building Code.

The major benefits to be gained in applying these standards are the harmonization of

-professional practice and the ensuring of appropriate levels of safety, health and economy with due

Consideration of the objective conditions and needs of the country.

As these standards are technical documents which, by their very nature, require periodic updating, revised editions will be issued by the Ministry from time to time as appropriate.

The Ministry welcomes comments and suggestions on all aspect of the Ethiopian Building Code Standards. All feedback received will be carefully reviewed by professional experts in the field of building construction with a view to possible incorporation of amendments in future Ministry of Works and

Definitions

1. Unless otherwise stated in the following, the terminology used in the International Standard ISO 8930: 1987 is adopted. Note: Most definitions are reproduced from ISO 8930: 1987.
2. The following terms are used in conmen for EBCS 1 to 8 with the following meaning:

a) **Construction Works:** Everything that is constructed or results from construction operations. This definition accords with ISO 6707: Part 1. The term covers both building and civil engineering works. It refers to the complete construction works comprising structural, III structural and geotechnical elements.

b) **Type of building or civil engineering works:** Type of construction works designating it s intended purpose, e.g. dwelling house, retaining wall, industrial building, Road Bridge.

c) **Type of construction:** Indication of principal structural material, e.g. reinforced concrete construction, steel construction, timber construction, masonry construction, composite steel and concrete construction.

d) **Method of construction:** Manner in which the execution will be carried out, e.g. cast in place, prefabricated, cantilevered.

e) **Construction material:** Material used in construction work, e.g. concrete, steel, timber, masonry I

f) **Structure:** Organized combination of connected parts designed to provide some measure of. rigidity. ISO 6707: Part 1 gives the same definition but adds It or a construction works having such an arrangement".

g) Form of structure: The arrangements of structural elements, such as beam, column, arch, foundation piles. Forms of structure are, for example, frames, suspension bridges.

h) Structural system: The load-bearing elements of a building or civil engineering works and the way in which these elements function together.

i) Structural model: The idealization of the structural system used for the purposes of analysis : and design.

j) Execution: The activity of creating a building or civil engineering works. The term covers –t work on site; it may also signify the fabrication of components off site and their subsequent erection on site. Special terms relating to design in general are:

    a. Design criteria: The quantitative formulations ~'hich describe for each limit state the conditions to be fulfilled.

II. Design situations: Those sets of physical conditions representing a certain time interval for which the design will demonstrate that relevant limit states are not exceeded.

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III. Persistent design situation: Design situation which is relevant duri?g a period of the same .I order as the design working life of the structure. Generally it refers to conditions of normal f use

IV. Accidental design situation: Design situation involving exceptional conditions of the structure or its exposure, e.g. fire, explosion, impact or local failure.

V. Design working life: The assumed period for which a structure is to be used for its intended purpose with anticipated maintenance but without substantial repair being necessary

VI. Hazard: Exceptionally unusual and severe event, e.g. an abnormal action or environmental ~ influence, insufficient strength or resistance, or excessive deviation form intended dimensions.

VII. Load' arrangement: Identification of the position, magnitude and direction of a free action.

VIII. Load case: Compatible load arrangements, sets of deformations and imperfections I considered simultaneously with fixed variable actions and permanent actions for a particular ;.verification.

IX. Limit states: States associated with collapse, or with other similar forms of structural failure. They generally correspond to the maximum load-carrying resistance of a structure or .." structural part.

X. Ultimate limit states: States associated with collapse, or with other similar forms of structural failure. They generally correspond to the maximum load-carrying resistance of a structure or structural part.

XI. Serviceability limit states: States which correspond to conditions beyond v,.hich specified or structural element are no longer met.

XII. **Irreversible serviceability limit states:** Limit states which will remain permanently exceeded

XIII. Reliability: Reliability covers safety, serviceability and durability of a structure.

1.1.2 EEPCO Regulations

Council of ministers regulation to provide for the establishment of the Ethiopian electric utility

This Regulation is issued by the Council of Ministers pursuant to Artic!e 5 of the Definition of Powers and Duties of the Executive Organs of the Federal Democratic Republic of Ethiopia Proclamation No. 69112010 and Article 47(1)(a) of the Public Enterprises Proclamation No. 25/1992.

I. **Short Title**

This Regulation may be cited as the "Ethiopian Electric Utility Establishment Council of Ministers Regulation No. 303/2013".

2. **Establishment**

1. The Ethiopian Electric Utility (hereinafter the"Enterprise") is hereby established as a public enterprise.
2. The Enterprise shall be governed by the Public Enterprises Proclamation No. 2511992.

3. **Supervising Authority**

The Ministry of Water, Irrigation and Energy shall be the supervising authority of the Enterprise.

Head office

4. The Enterprise shall have its head office in Addis Ababa and may have branch offices elsewhere. as may

5. p**urpose**

The purposes for which the Enterprise is established are:

1) to construct and maintain electric distribution networks; to contract out the distribution networks construction to contractors as required;
2) to administer electric distribution networks, to purchase bulk electric power and sell electric energy to customers;
3) to initiate electric tariff amendments and, upon approval, to implement same;

4) in line with directives and policy guidelines issued by the Ministry of Finance and Economic Development, to sell and pledge bonds and to negotiate and sign loan agreements with local and international financial sources;

5) to undertake any other related activities necessary for the attainment of its purposes.

6. **Capital**

The authorized capital of the Enterprise is Birr 64,715,822,693.20 (Sixty Four Billion Seven Hundred Fifteen Million Eight Hundred Twenty Two Thousand Six Hundred Ninety Three Birr and Twenty Cents) of which Birr 16,178,955,673.30 (Sixteen Billion One Hundred Seventy Eight Million Nine Hundred Fifty Five Thousand Six Hundred Seventy Three Birr and Thirty Cents) is paid up in cash and in kind. Liability

7. **Liability**.: The Enterprise may not be held liable beyond its total asset.

8. **Duration:** The Enterprise is established for an indefinite duration.

9. **Repealed Regulation** : The Ethiopian Electric Power Corporation Re Establishment Council of Ministers Regulation No. 170/2009 is hereby repealed.

10. **Transfer of Rights and Obligations**

The rights and obligations of the Ethiopian Electric

Power Corporation re-established undcr the Council of Ministers Regulation No. 17012009. other than those rights and obligations directly related to its **power generation, transmission and substation·** activities, are hereby transferred to the Enterprise.

1.1.3 OH & S guidelines

. Occupational safety and health policy

The trainees , in consultation with workers and their representatives, should set out in writing an OSH policy, which should be:

- specific to the organization and appropriate to its size and the nature of its activities;

- concise, clearly written, dated and made effective by the signature or endorsement of the employer or the most senior accountable person in the organization;
- communicated and readily accessible to all persons at their place of work;
- reviewed for continuing suitability; and
- made available to relevant external interested parties, as appropriate.

The OSH policy should include, as a minimum, the following key principles and objectives to which the organization is committed:

- Protecting the safety and health of all members of the organization by preventing work-related injuries, ill health, diseases and incidents;
- Complying with relevant osh national laws and regulations, voluntary programmes, collective agreements on osh and other requirements to which the organization subscribes;
- Ensuring that workers and their representatives are consulted and encouraged to participate actively in all elements of the OSH management system; and

  continually improving the performance of the OSH management system.

The OSH management system should be compatible with or integrated in other management systems in the organization.

Occupational safety and health objectives

Consistent with the OSH policy and based on the initial or subsequent reviews, measurable OSH objectives should be established, which are:

- specific to the organization, and appropriate to and according to its size and nature of activity;
- consistent with the relevant and applicable national laws and regulations, and the technical and business obligations of the organization with regard to OSH;
- focused towards continually improving workers' OSH protection to achieve the best OSH performance;
- realistic and achievable;
- documented, and communicated to all relevant functions and levels of the organization; and
- periodically evaluated and if necessary updated

Self-Check -1	Written Test

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

Directions: For the following questions, say TRUE if the statement is Correct and FALSE if it is incorrect (wrong).

1. Policy is a statement about an issue in the workplace.
2. Glove protects eyes of the workers during welding of metal works.
3. Health and safety policies and procedures are part of a framework for effective health and safety management.

Answer the following question!

Note: Satisfactory rating – 4 and 6 points Unsatisfactory - below 4and 6points

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

Answer Sheet

Name: ____________________________ Date: ____________

Score = ____________

~~Rating:~~ ____________

Information Sheet 2- Reading and interpreting work instruction

2.1 Reading and interpreting work instruction

Work Instruction

A Work Instruction is a document that provides specific instructions to carry out an Activity. A Work Instruction is a step by step guide to perform a single instruction. A Work Instruction contains more detail than a Procedure and is only created if detailed step-by-step instructions are needed.

Hierarchy of Procedural Documents

Another way to look at this is to consider all procedure documents, from SOPs to Work Instructions, as part of a pyramid.

- **Work Instructions** are the "how you address satisfying the SOP" documents.
- **Standards** state that you must have a documented procedure for conducting audits.
- **SOPs/Procedures** outlines how/when audits will be performed. Work Instructions go one level down and show the exact steps required to train the auditors, prepare the documents etc.

Purpose of work instruction

- Work instructions reduce risk
- Avoid errors and "the blame game"

- Save time
- good instruction look like

Steps to clear work instructions

Step 1:- Write a clear title

What's in an introduction? Well, quite a lot actually. It is crucial to get this part right. To do so make sure you do the following:

- Give some context: briefly, explain which process the task is part of.
- Identify the owners: briefly, explain who the process owner is an who the task owner is
- State the output: briefly, explain what the output or purpose of the task is
- The title must refer to the job: A good example might be, "how to disinfect your hands".

Step 2:- Describe the purpose the why

What's the purpose of your work instruction? Why are you preparing it? Asking why questions help you to step back and think about what you're trying to achieve. The answer to the why isn't simply the output you have already identified. Asking why is about deepening your understanding before jumping into the details. Read more about the value of the questions why

Step 3:- **Describe how to do it**

First of all, you need to list the materials required to do the job. For easy reading, it's best to list these in bullet points and to distinguish between the materials that are provided and not provided. Order your bullet point list logically. For example, in the case of disinfecting hands:

- Household soap
- Liquid antimicrobial soap in a dispenser
- Running water

- Towels

Include any relevant or helpful references directly into the text as natural hyperlinks. This makes it easy for your reader to clarify things..

Step 4:- Format for easy reading

Think of your work instruction document as an educational tool. Put yourself in the reader's shoes and think about what would help him or her digest the document.

1. Choose how you will format the document and stick with it. If you are practising Lean, then here's an example format to consider using.
2. Break down any steps into a number sequence. If there are more than 10 steps, then subdivide the different topics. One step describes one action that takes no more than 15 seconds to complete.
3. Use images or drawings. Make sure the image fits the text. Refer to the image in the text. Place images on the left side of the paper and keep the text on the right side.
4. Emphasizes important information by using upper case, bold or italicized text.
5. Turn any list into a bulleted or numbered list

Step 5:- Rewrite and simplify

The key rule for good writing is brevity. Short, simple and clear.

1. Use short and simple sentences. Sentences should be no longer than 15 words and should be without clauses.
2. Use short and simple words. Multi-syllable words sound brainy but slow the reader down. Make it easy for them and imagine you're writing for a five-year-old.
3. Avoid acronyms, and if you must use one then spell it out the first time and enclose the acronym in brackets next to it. Use the acronym from then on.
4. Include a list of abbreviations the reader can refer to.

5. Decide which word or term you will use to describe something and stick with that. Don't use different words for the same thing. For example, if you use the term "household soap" then only use that throughout the whole document.

As discussed above, use active sentences, not passive:

Correct: Dry your hands thoroughly.

Incorrect: Your hands should be dried thoroughly.

Step 6:- Add references

It's always helpful to provide sources and suggestions for further reading and learning. Either add footnotes or have an appendix at the end of the document.

Step 7:- Test with a colleague

To make sure your work instructions are easy to understand and follow, ask a colleague to perform the task by following it. This will tell you if certain parts or explanations are confusing or need further clarification.

1. Ask an appropriate colleague to read the draft of your work instruction and to give you feedback on it. Does the work instruction match the way the task is performed in reality? Is it confusing? What could be clearer?
2. Request the colleague to perform the job by following the draft work instruction. Do NOT help him/her, or give further explanations. Observe.
3. Make notes of what should be added or changed on your copy of the work instruction.

Table 1 Main Differences between Process, Procedure and Work Instruction

PROCESS	PROCEDURE	WORK INSTRUCTION
Flow of sequences of activities that transform input	Specific way to carry out a process	Describe the correct steps to

elements into results		perform a specific task.
What we do By WHOM Where it takes place When it happens	How the work has to been performed and why	How accomplish a specific task within a process with very detailed directions
Orchestration the work	Mandatory method	Mandatory guidance
Can respond to 0, 1 or more procedures	It may consist of 0, 1 or more work instructions	Focus on the instructions of 1 task
Transversal by Business Units	Cross-Functional or only 1 business unit	Only 1 business unit
Participate more than one role	Participate more than one role	Participate only one role
Encapsulates activities	Explains how to do but doesn't get to the all details of how it is done	All the detail of all the steps to follow in an activity
Provides the workflow model in BPMN at a high level	Document with both narrative and images, usually in the form of use cases and workflow diagrams	Document with the maximum detail that explains step by step the instructions that must be carried out in an activity

Your work instruction checklist

To summaries and simplify, here's a checklist for you to have on hand when you're planning how to write your next work instruction.

- Identified process the task is part of
- Identified the purpose of the task
- Understood the task's scope
- Named people responsible for the task

- Stated tools required for the task
- Mentioned any safety requirements
- Chosen an appropriate and helpful format
- Used helpful visual aids
- Checked for simple language and short sentences
- Removed unnecessary jargon and technical terms
- Tested on a colleague.

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Self-Check -2	Written Test

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

<u>Directions</u>: For the following questions, say TRUE if the statement is correct and FALSE if it is incorrect (wrong).

1. Work Instruction is a document that provides specific instructions to carry out an activity.
2. Work instructions not reduce risk.
3. The key rule for good writing is brevity
4. Work Instruction contains more detail than a Procedure.
5. Every employee should be able to understand work instructions

. Answer the following question!

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

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

Score = ___________
Rating: ____________

Answer Sheet

Name: _________________________ Date: _______________

Information Sheet 3. Selecting tools and Testing devices

3.1 Selecting tools and testing devices

Methods for Selection of Measuring Instruments

The selection of measuring instruments for linear measurements, takes the following main factors into account: manufacturing program, the construction features of the details and manufacturing accuracy – the tolerance zone (IT), measuring instrument error and the measuring costs. In the single production companies the special measurement instruments are inapplicable, so it is recommended the dimensions control of manufacturing products to be made using universal measuring equipment (calipers, micrometers, indicating internal gages i.e.).

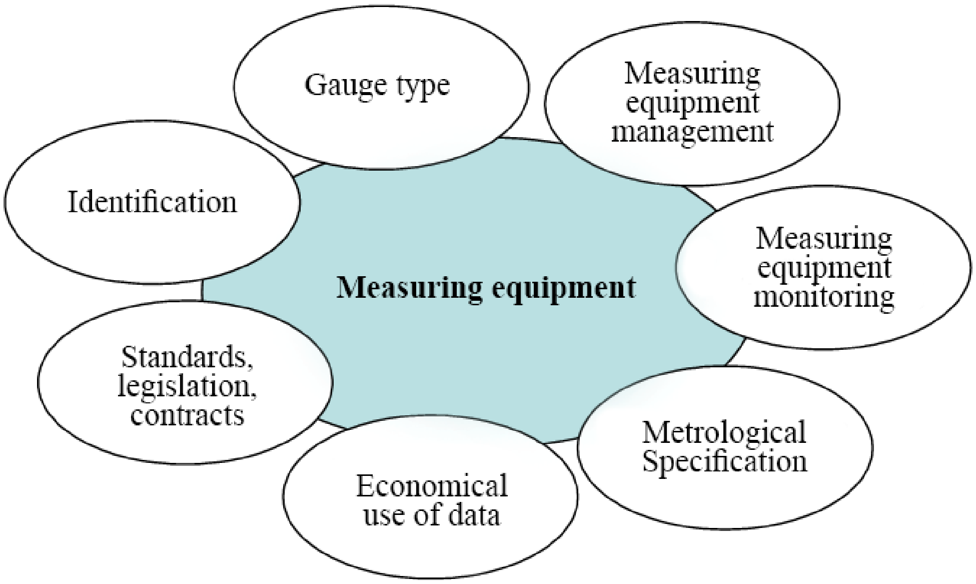

Fig.2 Information about the measuring equipment

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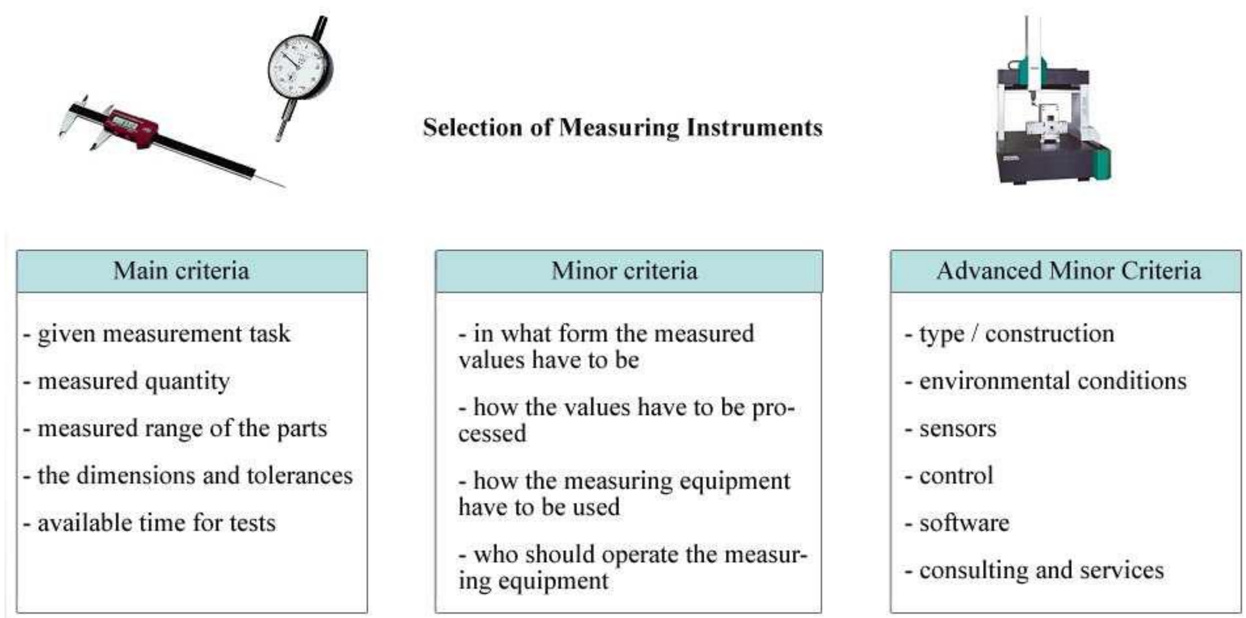


Fig. 3. Criteria for selection of measuring equipment

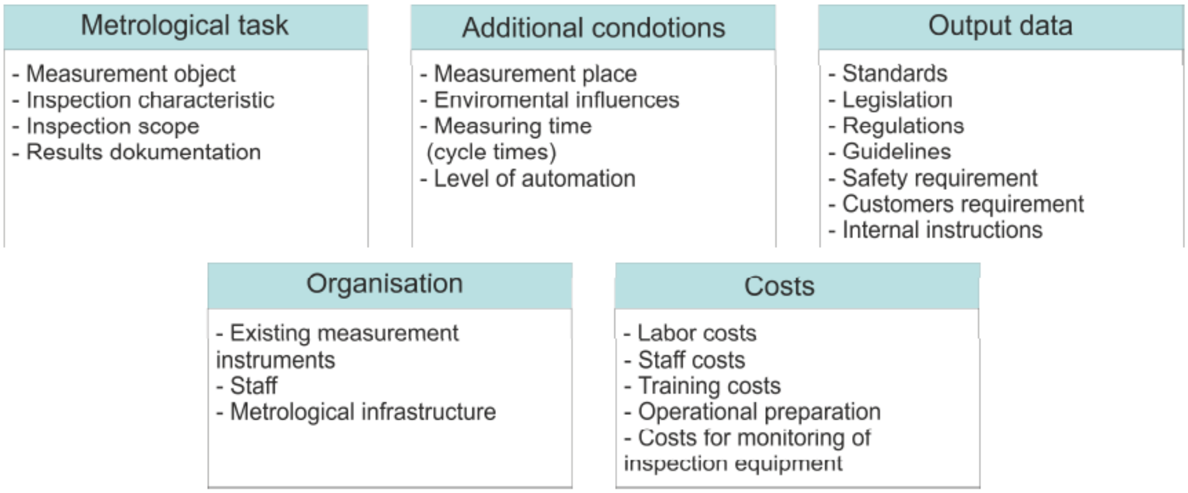


Fig.4 Factors for selection of measurement instruments

3.1.1 Tools for installation works

- Pliers (assorted)
- Screwdrivers (assorted)
- Wrenches (assorted)

Pliers

Pliers are a hand tool used to hold objects firmly, possibly developed from tongs used to handle hot metal in Bronze Age Europe. They are also useful for bending and compressing a wide range of materials.

1. Pliers come in several shapes and with several types of jaw action. Simple combination or slip joint pliers will do most jobs for which you need pliers. The slip joint allows the jaws to expand to grasp a larger size work piece.

Fig4 of combination pliers

2. They are measured by overall length and are made in 5-, 6-, 8-, and 10-in. sizes.

3. **Interlocking joint pliers,** or water pump pliers, were made to tighten packing gland nuts on water pumps on cars and trucks but are useful for a variety of jobs. Pliers should never be used as a substitute for a wrench, as the nut or bolt head will be permanently deformed by the serrations in the plier jaws, and the wrench will no longer fit properly. Round nose pliers are used to make loops in wire and to shape light metal.

4. **Needle nose pliers** are used for holding small delicate work pieces in tight spots. They are available in both straight and bent nose types. Linemen's pliers can be used for wire cutting and bending. Some types have wire stripping grooves and insulated handles. Diagonal cutters are used only for wire cutting.

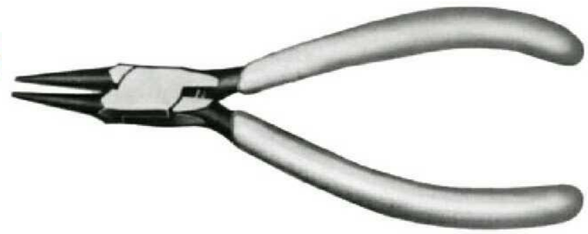
 

Fig 5 a) Bent nose plier b) Round nose plier

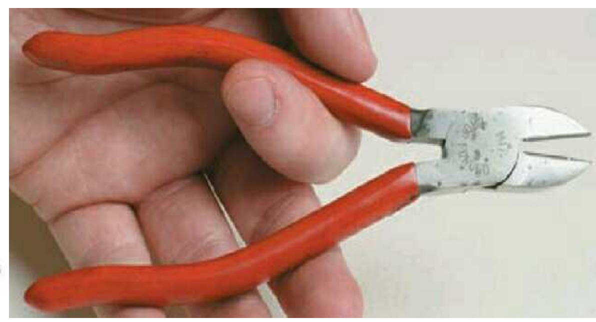
 

Fig 6 c) Long nose straight pliers d) side cutting pliers

Screwdrivers

A **screwdriver** is a tool, manual or powered, used for screwing (installing) and unscrewing (removing) screws.

A screwdriver is classified by its tip, which is shaped to fit the driving surfaces slots, grooves, recesses, etc. on the corresponding screw head. Proper use requires that the screwdriver's tip engage the head of a screw of the same size and type designation as the screwdriver tip. Screwdriver tips are available in a wide variety of types and sizes (List of screw drives). The two most common are the simple 'blade'-type for slotted screws, and Phillips, generically called "cross-recess", "cross-head", or "cross-point".

The two types of screwdrivers that are most used are the standard Flat and Phillips. Both types are made in various sizes and in several styles: straight shank, and offset. It is important to use the right width blade when installing or removing screws. The shape of the tip is also important. If the tip is badly worn or incorrectly ground, it will tend to jump out of the slot. Never use a screwdriver as a chisel or pry bar. Keep a screwdriver in proper shape by using it only on the screws for which it was meant.

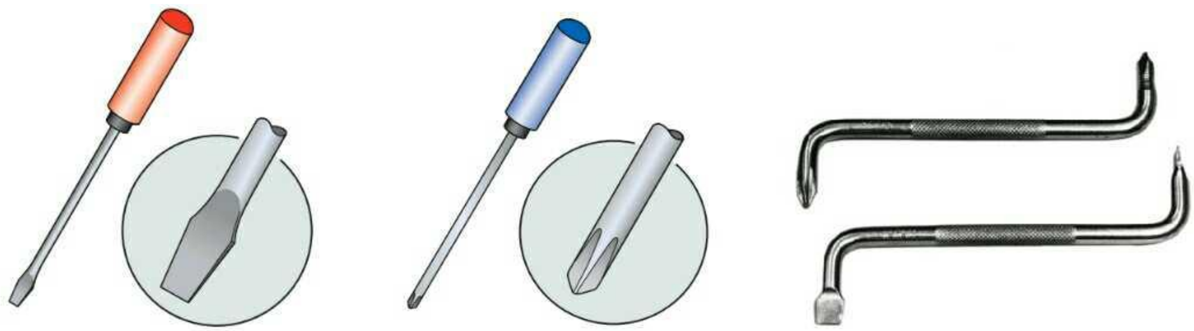


Fig 7 a) Flat Screwdriver. b) Phillips screw driver c) Standard offset screwdrivers.

Wrenches

A wrench or spanner is a tool used to provide grip and mechanical advantage in applying torque to turn objects usually rotary fasteners, such as nuts and bolts—or keep them from turning. Refer level I unit of competency 1 use hand tools and testing instrument A large variety of wrenches are made for different uses such as turning cap screws, bolts, and nuts. The adjustable wrench, commonly called a crescent wrench, is a general purpose tool and will not suit every job, especially those requiring work in close quarters. The wrench should be rotated toward the movable jaw and should fit the nut or bolt tightly.

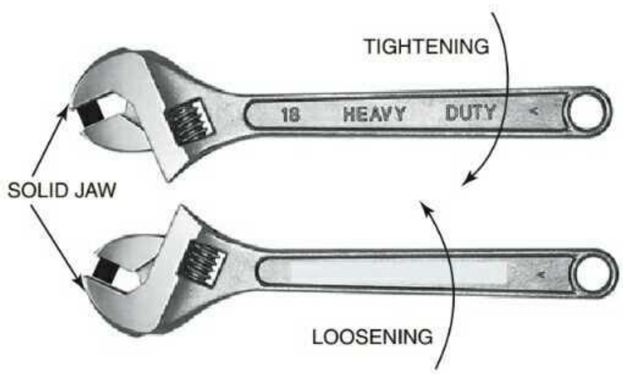


Fig 8 adjustable wrench

The size of the wrench is determined by its overall length in inches. Open end wrenches

are best suited to square-headed bolts, and usually fit two sizes, one on each end. The ends of this type of wrench are angled so they can be used in close quarters. Box wrenches are also double ended and offset to clear the user's hand. The box completely surrounds the nut or bolt and usually has 12 points so that the wrench can be reset after rotating only•

Fig 9 non adjustable wrench

Adjustable wrench showing the correct direction of pull. The movable jaw should always face the direction of rotation a partial turn. Mostly used on hex-headed bolts, these wrenches have the advantage of precise fit. Combination and open end wrenches are made with a box at one end and an open end at the other.

Socket wrenches are similar to box wrenches in that they also surround the bolt or nut and usually are made with 12 points contacting the six-sided nut. Sockets are made to be detached from various types of drive handles.

Fig 10 Socket wrench set.

Pipe wrenches, as the name implies, are used for holding and turning pipe. These wrenches have sharp serrated teeth and will damage any finished part on which they are used. Strap wrenches (Figure B-50) are used for extremely large parts or to avoid marring the surface of tubular parts.

Spanner wrenches come in several basic types, including face and hook. Face types are sometimes called pin spanners. Spanners are made in fixed sizes or adjustable types. Socket head wrenches are six-sided barshaving a 90-degree bend near one end. They are used with socket head cap screws and socket setscrews. Torque wrenches are widely used by machinists and mechanics to provide the correct amount of tightening torque on a screw or nut. A dial reads in English measure (inch-pounds and foot-pounds) or in metric measure (kilogram-centimeters and newton-meters).

3.1.2 Testing device

- Multi-tester (VOM)
- Ammeter
- Signal generator
- Calibrators
- Flow meters
- Thermometer
- Low voltage power supply (DC)

- Computers (PC/lap)/Programming console

Definition of instrumentation

An instrument can be defined as **a** device that communicates, denotes, detects, indicates, measures, observes, records, or signals a quantity or phenomenon, or controls or manipulates another device.

Use of electrical test instruments

Due to the potential electrical hazards associated with the use of electrical test instruments, only qualified persons are permitted to perform tasks such as testing, troubleshooting and voltage measuring when working within the Limited Approach Boundary of exposed energized electrical conductors or circuit parts operating at 50 volts or more, or where any other electrical hazard may exist. Improper use of electrical test instruments can result in shock or electrocution, as well as creating an arc flash incident.

The following additional requirements apply to test instruments, equipment, and all associated test leads, cables, power cords, probes, and connectors:

- Must be rated for circuits and equipment where they are utilized.
- Must be designed for the environment to which they will be exposed and for the manner in which they will be utilized.
- Must be visually inspected for external defects and damage before each use. If there is a defect or evidence of damage that might expose an employee to injury, the defective or damaged item shall be removed from service.

When test instruments are used for testing the absence of voltage on conductors or circuit parts operating at 50 volts or more, the operation of the test instrument must be:

- Verified on a known voltage source before an absence of voltage test is performed.

- Test for the absence of voltage on the de-energized conductor or circuit part. A zero reading might mean that no voltage is present during the testing, or it could mean that the instrument has failed.
- Verified on a known voltage source after an absence of voltage test is performed.

This verification primarily applies to conductors or circuit parts operating at 50 volts or more. However, under certain conditions (such as wet contact or immersion) even circuits operating under 50 volts can pose a shock hazard.

Only qualified persons are permitted to perform tasks such as testing, troubleshooting, and voltage measuring, due to the electrical hazards associated with energized work. All required PPE, for the associated hazards, must be utilized when performing these tasks. Test instruments must be rated for the conditions under which testing is to be performed. When selecting voltage testing instruments, an assessment must be performed to determine the proper category (CAT) rating required, based on the highest hazard exposure.

When test instruments are used for testing the absence of voltage, for de-energized work, on conductors or circuit parts operating at 50 volts or more, the operation of the test instrument must be verified on a known voltage source before and after an absence of voltage test is performed.

A test instrument is a device used to inspect, measure, test, or examine parts in order to determine compliance with required specifications. To test means to carry out an examination on a system by applying some chemical or physical procedure designed to indicate the presence of a substance or the possession of a property. Testing equipment can be put to good use ensuring that electrical equipment is properly installed and safe to operate. Faulty installations can be lethal; the condition of electrical installations can be established when contractors use test equipment. These test instruments include the following listed below:

Electronic test equipment

An electronic test equipment is used to create signals and capture responses from electronic Devices Under Test **(DUTs)** and they are used to prove or test faults in the device. Use of electronic test equipment is essential to any serious work on electronics systems. Practical electronics engineering and assembly requires the use of many different kinds of electronic test equipment ranging from very simple inexpensive to extremely complex and sophisticated

Types of test equipment

The following items are used for basic measurement of voltages, currents, and components in the circuit under test.

- Voltmeter (to Measure voltage)
- Ohmmeter (to Measure resistance)
- Ammeter, e.g. Galvanometer or Milliameter (to Measure current)
- Multimeter e.g., VOM (Volt-Ohm-Milliameter) or DMM (Digital Multimeter- to Measure all of the above)

The following are used for stimulus of the circuit under test depending on what is tested for:

- Power supplies

- Signal generator
- Digital pattern generator
- Pulse generator

The following analyze the response of the circuit under test:

- Oscilloscope (to displays voltage as it changes over time)
- Frequency counter (to anayze or measures frequency)

Advanced or less commonly used **Meters** equipment in technical institutes

- Solenoid voltmeter (also called the Wiggy voltmeter)
- Clamp meter (which is current transducer)
- Wheatstone bridge (to Precisely measure resistance)
- Capacitance meter (to Measure capacitance)
- LCR meter (to Measure inductance, capacitance, resistance and combinations)
- EMF Meter (to Measure Electric and Magnetic Fields)
- Electrometer (to Measure charge)

Types of commonly used analyzers include

- Logic analyzer – (Tests digital circuits)
- Spectrum analyzer (SA) (to Measure spectral energy of signals
- Protocol analyzer (to Test functionality, performance and conformance of protocols)
- Vector signal analyzer (VSA)
- Wave analyzer (to analyze waves)

Electrical testing, maintenance of power systems and equipment is essential to ensure maximum operational reliability and safety. Having the right electrical testing devices and supplies in your toolbox is critical and thus a **digital multimeter** should be at the top of your list. It allows a highly accurate reading of voltage, current, resistance. It makes it much easy for fault finding andfield service work.

AC Current Line Splitters

Capacitor Testers

Clamp Meters

Analog Multimeters

Circuit Tracer Accessories

Clamp On Earth Resistance Testers

Cable Height Meters

Circuit Tracers

Clamp On Power Meters


Multifunction Testers


Multimeter Accessories


Phasing and Motor Rotation Meters


Power-Meters Analyzers


Power-Meters-Analyzers Accessories


Receptacle and GFCI Tester Accessories


Receptacle and GFCI Testers


Receptacle Tension Tester


Test Clips and Probes


Test Instrument Carrying Cases


Test Lead Connectors


Test Lead Kits


Tool & Appliance Testers


Transformer Turns Ratio Tester


Underground Utility Locator Accessories


Undergr Utility Locators


Voltage and Continuity Testers


Voltage Detectors


Wire Sorters

Ammeter

An ammeter, also known as a galvanometer, is an instrument used to measure the flow of electric current in a circuit. Ammeters must be inserted into the circuit and become part of it in order to measure current. However, a clamp meter, or clamp-on ammeter, is a type of ammeter that measures electrical current without the need to disconnect the wiring through which the current is flowing.

MULTIMETER

A **multimeter** is also known as **multitester** or **VOM** (Volt-Ohm meter). It is an electronic measuring instrument that combines several measurement functions in one unit. It includes basic features such as the ability to measure **voltage, current, and resistance**. A multimeter can be a hand-held device useful for basic fault finding and field service work or a bench instrument which can measure to a very high degree of accuracy. They can be used to troubleshoot electrical problems in a wide array of industrial and household devices such as electronic equipment, motor controls, domestic appliances, power supplies, and wiring systems.

Analog multimeters

Analog multimeters use a micro-ammeter whose pointer moves over a scale calibrated for all the different measurements that can be made. An un-amplified analog multimeter combines a meter movement, range resistors and switches. For an analog meter movement, DC voltage is measured with a series resistor connected between the meter movement and the circuit under test. A set of switches allows greater resistance to be inserted for higher voltage ranges. The product of the basic full-scale deflection current of the movement, and the sum of the series resistance and the movement's own resistance, gives the full-scale voltage of the range.

Low-resistance shunts are connected in parallel with the meter movement to divert most of the current around the coil. Moving coil instruments respond only to the average value of the current through them. To measure alternating current, a rectifier diode is inserted in the circuit so that the average value of current is non-zero.

To measure resistance, a small battery within the instrument passes a current through the device under test and the meter coil. Since the current available depends on the state of charge of the battery, a multimeter has an adjustment for the ohms scale to zero it. The meter deflection is inversely proportional to the resistance; so full-scale is 0 ohms and high resistance corresponds to smaller deflections. The ohms scale is compressed, so resolution is better at lower resistance values. Amplified instruments simplify the design of the series and shunt resistor networks. The internal resistance of the coil is decoupled from the selection of the series and shunt range resistors. Where AC measurements are required, the rectifier can be placed after the amplifier stage, improving precision at low range.

Fig15 analogue multimeter

Digital multimeter

Digital multimeters display the measured value in numerals digits. The display a bar of a length proportional to the quantity being measured. Digital multimeters are more common than analog ones, but analog multimeters are still preferable when monitoring a rapidly varying value.

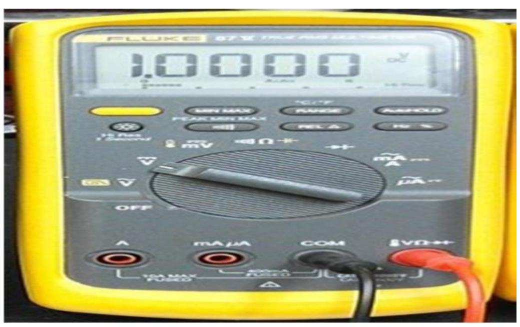


Fig16 digital multimeter

Digital instruments use the same principles as analog instruments for range resistors. For resistance measurements, a small constant current is passed through the device under test and the digital multimeter reads the resultant voltage drop. An auto ranging digital multimeter can automatically adjust the scaling network so that the measurement uses the full precision of the A/D converter.

CATHODE RAY OSCILLOSCOPE

An **oscilloscope** is informally known as a scope or CRO for cathode-ray oscilloscope. Modern digital storage oscilloscope (DSO) is a type of electronic test instrument that allows observation of constantly varying signal voltages in two-dimensional plot of one or more signals as a function of time. Non-electrical signals such as sound or vibration) can be converted to voltages and displayed. Oscilloscopes are used to observe the change of an electrical signal over time such that voltage over time and describe a shape which is continuously graphed against a calibrated scale. The observed waveform can be analyzed for such properties as amplitude, frequency, rise time, time interval, distortion and others. Modern digital instruments calculate and display these properties directly.

The oscilloscope can be adjusted so that repetitive signals can be observed as a continuous shape on the screen. A storage oscilloscope allows single events to be captured by the instrument and displayed for a relatively long time, allowing human observation of events too fast to be directly perceptible. They are s are used in the sciences, medicine, engineering, and telecommunications industry. Special-purpose oscilloscopes are used for such purposes as analyzing an automotive ignition system or to display the waveform of the heartbeat as an electrocardiogram. Storage oscilloscopes use special storage CRTs to maintain a steady display of a single brief signal.

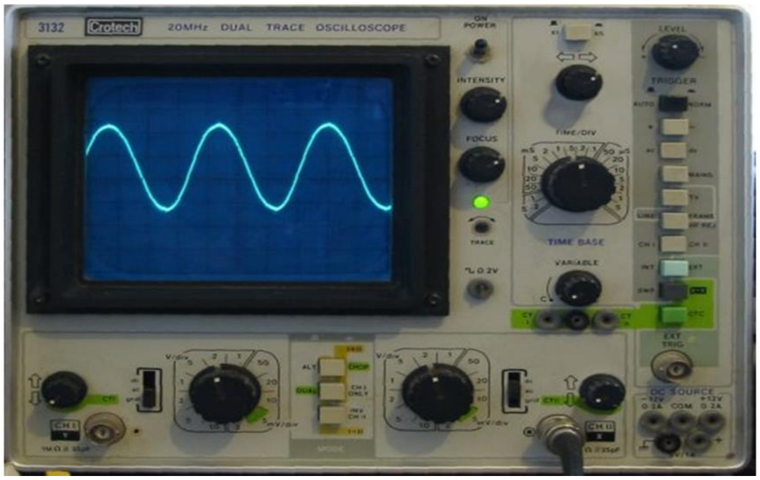


Fig 17 oscilloscope

Features of CRO and their uses

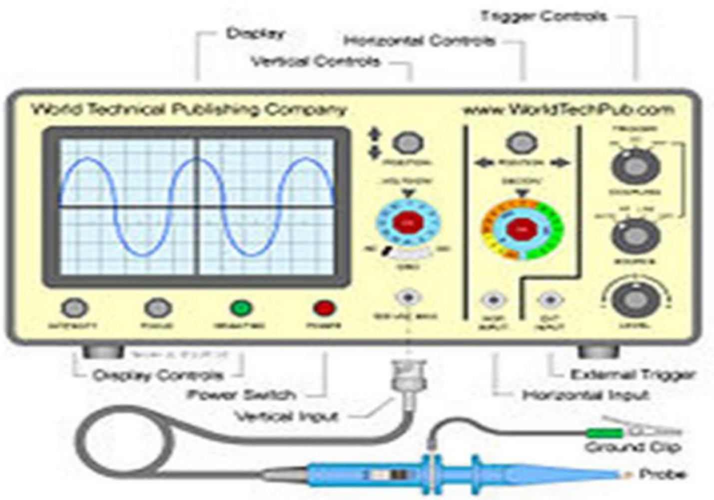


Fig17 Features of CRO

Major sections of a CRO

The basic oscilloscope is divided into four sections:

1. The display,
2. Vertical controls,
3. Horizontal controls and
4. Trigger controls.

The display is usually a CRT or LCD panel which is laid out with both horizontal and vertical reference lines referred to as the graticule. In addition to the screen, most display sections are equipped with three basic controls: a focus knob, an intensity knob and a beam finder button.

The vertical section controls the amplitude of the displayed signal. This section carries a Volts- per-Division (Volts/Div) selector knob, an AC/DC/Ground selector switch and the vertical) input for the instrument. This section is equipped with the vertical beam position knob.

The horizontal section controls the time base or "sweep" of the instrument. The primary control is the Seconds-per-Division (Sec/Div) selector switch. It includes a horizontal input for plotting dual X-Y axis signals. The horizontal beam position knob is y located in this section.

The trigger section controls the start event of the sweep. The trigger can be set to automatically restart after each sweep or it can be configured to respond to an internal or external event. The principal controls of this section will be the source and coupling selector switches.

In addition to the basic instrument, most oscilloscopes are supplied with a probe. The probe will connect to any input on the instrument and has a resistor of ten times the oscilloscope's input impedance.

Size and portability

Most modern oscilloscopes are lightweight, portable instruments that are compact enough to be easily carried by a single person

The Inputs

The signal to be measured is fed to one of the input connectors, which is a coaxial connector such as a BNC or UHF type. Binding posts are used for lower frequencies. If the signal source has its own coaxial connector, then a simple coaxial cable is used. General-purpose oscilloscopes present an input impedance of 1 megohm in parallel with a small but known capacitance such as 20 picofarads. Scopes for use with very high frequencies may have 50-ohm inputs, which must be either connected directly to a 50-ohm signal source or used with Z_0 or active probes. Less- frequently-used inputs include one (or two) for triggering the sweep, horizontal deflection for X-Y mode displays, and trace brightening/darkening, sometimes called z'-axis inputs.

Oscilloscope probes

Open wire test leads are likely to pick up interference, so they are not suitable for low level signals. Furthermore, the leads have a high inductance, so they are not suitable for high frequencies. Using a shielded cable is better for low level signals. Coaxial cable has lower inductance, but it has higher capacitance: a 50 ohm cable has about 90 pF per meter.

To minimize loading, attenuator probes are used. A typical probe uses a 9 megohm series resistor shunted by a low-value capacitor to make an RC compensated divider with the cable capacitance and scope input. The RC time constants are adjusted to match. A 9 megohm series resistor is shunted by a 12.2 pF capacitor for a time constant of 110 microseconds. The cable capacitance of 90 pF in parallel with the scope input of 20 pF and 1 megohm also gives a time constant of 110 microseconds. In practice, there will be an adjustment so the operator can precisely match the low frequency time constant. Matching the time constants makes the attenuation independent of frequency. At low frequencies, the circuit looks like a resistive divider; at high frequencies the circuit looks like a capacitive divider.

The result is a frequency compensated probe for modest frequencies that presents a load of about

10 megohms shunted by 12 pF. Although such a probe is an improvement, it does not work when the time scale shrinks to several cable transit times. In that time frame, the cable looks like its characteristic impedance, and there will be reflections from the transmission line mismatch at the scope input and the probe that causes ringing. The modern scope probe uses lossy low capacitance transmission lines and sophisticated frequency shaping networks to make the 10X probe perform well at several hundred megahertz.

Probes with 10:1 attenuation are by far the most common; for large signals (and slightly-less capacitive loading), 100:1 probes are not rare. There are also probes that contain switches to select 10:1 or direct (1:1) ratios, but one must be aware that the 1:1 setting has significant capacitance (tens of pF) at the probe tip, because the whole cable's capacitance is now directly connected.

There are also current probes, with cores that surround the conductor carrying current to be examined. One type has a hole for the conductor, and requires that the wire be passed through the hole; they are for semi-permanent or permanent mounting. Other types, for testing, have a two-part core that permits them to be placed around a wire. Inside the probe, a coil wound around the core provides a current into an appropriate load, and the voltage across that load is proportional to current.

Front panel controls

Focus control

This control adjusts CRT focus to obtain the sharpest, most-detailed trace. Focus needs to be adjusted slightly when observing quite-different signals, which means that it needs to be an external control. Flat-panel displays do not need focus adjustments and therefore do not include this control.

Intensity control

This adjusts trace brightness. Slow traces on CRT oscilloscopes need less, and fast ones, especially if not often repeated, require more. On flat panels, however, trace brightness is essentially independent of sweep speed, because the internal signal processing effectively synthesizes the display from the digitized data.

Astigmatism

This is also be called "Shape" or "spot shape" and sdjusts the relative voltages on two of the CRT anodes such that a displayed spot changes from elliptical in one plane through a circular spot to an ellipse at 90 degrees to the first.

Beam finder

Modern oscilloscopes have direct-coupled deflection amplifiers, which means the trace could be deflected off-screen. They have their beam blanked without the operator knowing it. To help in restoring a visible display, the beam finder circuit overrides any blanking and limits the beam deflected to the visible portion of the screen. Beam-finder circuits often distort the trace while activated.

Graticule

The graticule is a grid of squares that serve as reference marks for measuring the displayed trace. These markings consist of a 1 cm grid with closer tick marks on the centre vertical and horizontal axis. One expects to see ten major divisions across the screen; the number of vertical major divisions varies. Comparing the grid markings with the waveform permits one to measure both voltage (vertical axis) and time (horizontal axis). Frequency can also be determined by measuring the waveform period and calculating its reciprocal.

On old and lower-cost CRT oscilloscopes the graticule is a sheet of plastic, often with light- diffusing markings and concealed lamps at the edge of the graticule. The lamps had a brightness control. Higher-cost instruments have the graticule marked on the inside face of the CRT, to eliminate parallax errors; better ones also had adjustable edge illumination with diffusing markings. Digital oscilloscopes generate the graticule markings on the display in the same way as the trace. External graticules protect the glass face of the CRT from accidental impact. Some CRT oscilloscopes with internal graticules have an unmarked tinted sheet plastic light filter to enhance trace contrast; this also serves to protect the faceplate of the CRT.

Accuracy and resolution of measurements using a graticule is relatively limited; better instruments sometimes have movable bright markers on the trace that permit internal circuits to make more refined measurements.

Time base control

These select the horizontal speed of the CRT's spot as it creates the trace; this process is commonly referred to as the sweep. In all but the least-costly modern oscilloscopes, the **sweep speed** is selectable and calibrated in units of time per major graticule division

A **continuously variable control** offers un calibrated speeds slower than calibrated. This control provides a range somewhat greater than that of consecutive calibrated steps, making any speed available between the extremes.

Hold off control

This varies the time (hold off) during which the sweep circuit ignores triggers. It provides a stable display of some repetitive events in which some triggers would create confusing displays. It is set to minimum, because a longer time decreases the number of sweeps per second, resulting in a dimmer trace.

Vertical sensitivity, coupling, and polarity controls

To accommodate a wide range of input amplitudes, a switch selects **calibrated** sensitivity of the vertical deflection. Another control, often in front of the calibrated-selector knob, offers continuously-variable sensitivity over a limited range from calibrated to less-sensitive settings. The observed signal is offset by a steady component, and only the changes are of interest. A switch (AC position) connects a capacitor in series with the input that passes only the changes. However, when the signal has a fixed offset of interest, or changes quite slowly, the input is connected directly (DC switch position). Most oscilloscopes offer the DC input option. Many oscilloscopes have a third switch position (GND) that disconnects the input and grounds it and user centers the trace with the Vertical Position control.

Horizontal sensitivity control

This control is found only on more elaborate oscilloscopes and offers adjustable sensitivity for external horizontal inputs.

The vertical position control moves the whole displayed trace up and down. It is used to set the no-input trace exactly on the center line of the graticule, but also permits offsetting vertically by a limited amount. With direct coupling, adjustment of this control can compensate for a limited DC component of an input.

Horizontal position control

The horizontal position control moves the display sidewise. It sets the left end of the trace at the left edge of the graticule, but it can displace the whole trace when desired. This control also moves the X-Y mode traces sidewise in some instruments, and can compensate for a limited DC component as for vertical position.

Dual-trace controls

Each input channel has its own set of sensitivity, coupling and position controls, although some four-trace oscilloscopes have only minimal controls for their third and fourth channels. Dual- trace oscilloscopes have a mode switch to select either channel alone, both channels, or an X-Y display, which uses the second channel for X deflection. When both channels are displayed, the type of channel switching can be selected on some oscilloscopes; on others, the type depends upon time-base setting. If manually selectable, channel switching can be free-running (asynchronous), or between consecutive sweeps. Multiple-trace oscilloscopes have a switch for each channel to enable or disable display of that trace's signal.

Delayed-sweep controls

These include controls for the **delayed-sweep time-base** which is calibrated and also variable. The slowest speed is several steps faster than the slowest main sweep speed, although the fastest is generally the same. A calibrated multi-turn delay time control offers wide range, high resolution delay settings; it spans the full duration of the main sweep, and its reading corresponds to graticule division. A switch selects display modes. Good CRT oscilloscopes include a delayed-sweep intensity control, to allow for the dimmer trace of a much-faster delayed sweep that nevertheless occurs only once per main sweep.

Sweep trigger controls

A switch selects the Trigger Source. It can be an external input, one of the vertical channels of a dual or multiple-trace oscilloscope, or the AC line (mains) frequency. Another switch enables or disables Auto trigger mode, or selects single sweep, if provided in the oscilloscope. A Level control varies the voltage on the waveform which generates a trigger, and the Slope switch selects positive-going or negative-going polarity at the selected trigger level.

Automatic sweep mode

Triggered sweeps can display a blank screen if there are no triggers. These sweeps include a timing circuit that generates free-running triggers so a trace is always visible. Once triggers arrive, the timer stops providing pseudo-triggers. Automatic sweep mode can be de-selected when observing low repetition rates.

Recurrent sweeps

If the input signal is periodic, the sweep repetition rate can be adjusted to display a few cycles o f the waveform. Measuring voltage or time is possible, but only with extra equipment, and is quite inconvenient.

X-Y mode

A 24-hour clock displayed on a CRT oscilloscope configured in X-Y mode as a vector monitor with dual R2R DACs to generate the analog voltages. Most modern oscilloscopes have several inputs for voltages, and can be used to plot one varying voltage versus another. This is useful for graphing I-V curves for components such as diodes, as well Lissajous patterns. Lissajous figures are an example of how an oscilloscope can be used to track phase differences between multiple input signals. This is very frequently used in broadcast engineering to plot the left and right stereophonic channels, to ensure that the stereo generator is calibrated properly. Stable Lissajous figures were used to show that two sine waves had a relatively simple frequency relationship, a numerically-small ratio. They also indicated phase difference between two sine waves of the same frequency.

The X-Y mode allows the oscilloscope to be used as a vector monitor to display images or user interfaces. Complete loss of signal in an X-Y CRT display means that the beam strikes a small spot, which risks burning the phosphor. Older phosphors burned more easily.

Band width

Oscilloscopes do not respond equally to all possible input frequencies. The range of frequencies an oscilloscope can usefully display is referred to as its bandwidth. Bandwidth applies primarily to the Y-axis, although the X-axis sweeps have to be fast enough to show the highest-frequency waveforms.

The bandwidth is defined as the frequency at which the sensitivity is 0.707 of that at DC or the lowest AC frequency (a drop of 3 dB). The oscilloscope's response will drop off rapidly as the input frequency is raised above that point. One source states that there is a noticeable effect on the accuracy of voltage measurements at only 20 percent of the stated bandwidth. Some oscilloscopes' specifications do include a narrower tolerance range within the stated bandwidth.

Other features

Some oscilloscopes have cursors, which are lines that can be moved about the screen to measure the time interval between two points, or the difference between two voltages. These cursors are more accurate than visual estimates referring to graticule lines.

Better quality general purpose oscilloscopes include a calibration signal for setting up the compensation of test probes, a 1 kHz square-wave signal of a definite peak-to-peak voltage available at a test terminal on the front panel. Some better oscilloscopes have a squared-off loop for checking and adjusting current probes.

Sometimes the event that the user wants to see may only happen occasionally. To catch these events, some oscilloscopes, known as "storage scopes", preserve the most recent sweep on the screen. This was originally achieved by using a special

CRT, a "storage tube", which would retain the image of even a very brief event for a long time.

Some digital oscilloscopes can sweep at speeds as slow as once per hour, emulating a strip chart recorder. The signal scrolls across the screen from right to left. Most oscilloscopes with this facility switch from a sweep to a strip-chart mode at about one sweep per ten seconds.

In current oscilloscopes, digital signal sampling is more often used for all but the simplest models. Samples feed fast analog-to-digital converters, following which all signal processing is digital.

Many oscilloscopes have different plug-in modules that include high-sensitivity amplifiers of relatively narrow bandwidth, differential amplifiers, amplifiers with four or more channels, sampling plugins for repetitive signals of very high frequency, and special-purpose plugins including audio/ultrasonic spectrum analyzers, and stable-offset-voltage direct-coupled channels with relatively high gain.

Dual-beam oscilloscope

The dual-beam analog oscilloscope can display two signals simultaneously. A special dual-beam CRT generates and deflects two separate beams. Although multi-trace analog oscilloscopes can simulate a dual-beam display with chop and alternate sweeps, those features do not provide simultaneous displays. The disadvantages of the dual trace oscilloscope are that it cannot switch quickly between the traces and it cannot capture two fast transient events.

Analog storage oscilloscope

Trace storage is an extra feature available on some analog scopes; they used direct-view storage CRTs. Storage allows the trace pattern that normally decays in a fraction of a second to remain on the screen for several minutes or longer. An electrical circuit can then be deliberately activated to store and erase the trace on the screen.

Digital oscilloscopes

While analog devices make use of continually varying voltages, digital devices employ binary numbers which correspond to samples of the voltage. In the case of digital oscilloscopes, an analog-to-digital converter (ADC) is used to change the measured voltages into digital information.

Mixed-signal oscilloscopes

A mixed-signal oscilloscope has two kinds of inputs, a small number of analog channels, and a larger number of digital channels. It provides the ability to accurately time-correlate analog and digital channels, offering a distinct advantage over a separate oscilloscope and logic analyzer. Digital channels may be grouped and displayed as a bus with each bus value displayed at the bottom of the display in hex or binary.

CRO Operation:

The signal to be displayed is amplified by the vertical amplifier and applied to the vertical deflection plates of the CRT. A portion of the signal in the vertical amplifier is applied to the sweep trigger as a triggering signal.

The **sweep trigger then generates** a pulse coincident with a selected point in the cycle of the triggering signal. This pulse turns on the sweep generator, initiating the saw-tooth wave form**.**

The saw-tooth wave is amplified by the horizontal amplifier and applied to the horizontal deflection plates.

Cathode-Ray Tube has the following:

(i) **Power and Scale Illumination** This controls and turns the CRO instrument on and controls illumination

(ii) Focus:It controls the illumination and thus focuses the spot or trace on the screen.

(iii) Intensity: It regulates the brightness of the spot or trace of the illumination.

Vertical Amplifier Section has the following:

(i) Position:- The position controls vertical positioning of oscilloscope display of the spot/wave.

(ii) Sensitivity::- This knob selects the sensitivity of the vertical amplifier in calibrated steps.

(iii) Variable Sensitivity: This knob provides a continuous range of sensitivities between the calibrated steps

(iv) AC-DC-GND:- This knob selects desired coupling (ac or dc) for incoming signal applied to vertical amplifier, or grounds the amplifier input.

Horizontal-Sweep Section has the following:

(i) Sweep time/cm:- The button selects desired sweep rate from calibrated steps or admits external signal to horizontal amplifier.

(ii) **Sweep time/cm Variable:**It provides continuously variable sweep rates. Calibrated position is fully clockwise.

(iii) Position:- This button controls the horizontal position of trace on screen.

(iv) **Horizontal Variable:** This variable knob controls the attenuation (reduction) of signal applied to horizontal amplifier through Ext. Horiz. connector.

Trigger Section{- The trigger selects the timing of the beginning of the horizontal sweep.

(i) Slope:-This button selects whether triggering occurs on an increasing (+) or decreasing (-) portion of trigger signal.

(ii) Coupling:- This knob selects whether triggering occurs at a specific dc or ac level or not.

(iii) Source:- This selects the source of the triggering signal from:

INT - (internal) - from signal on vertical amplifier

EXT - (external) - from an external signal inserted at the **EXT. TRIG.**
INPUT LINE - 60 cycle triger

(iv) Level:- It selects the voltage point on the triggering signal at which sweep is triggered. It also allows automatic (**auto**) triggering of allows sweep to run free (**free run**).

Connections for the Oscilloscope include the following:

(i) Vertical Input:- A pair of jacks for connecting the signal under study to the Y (or vertical) amplifier. The lower jack is grounded to the case of the CRO.

(ii) Horizontal Input:-A pair of jacks for connecting an external signal to the horizontal amplifier. The lower terminal is grounded to the case of the oscilloscope.

(iii) External Trigger Input:- Input connector for external trigger signal.

(iv) Cal. Out:- Provides amplitude calibrated square waves of 25 and 500 millivolts for use in calibrating the gain of the amplifiers.

Accuracy of the vertical deflection is + 3%. This sensitivity is variable. Horizontal sweep should be accurate to within 3%. This range of sweep is variable.

CRO Operating Instructions

Before plugging the Cathode Ray Oscilloscope (CRO) into a wall

Set the controls as follows:

(a) Power switch should be set to be off

(b) Intensity should be set to be fully counter clockwise

(c) Vertical centering should be set to be in the center of range

(d) Horizontal centering should be set to be in the center of range

(e) Vertical should be set at 0.2 (f) Sweep times should be set to 1

- Plug line cord into a standard ac wall receptacle (nominally 118 V).
- Turn power on.
- Do not advance the Intensity Control.
- Allow the scope to warm up for approximately two minutes, then turn the Intensity Control until the beam is visible on the screen.

WARNING:

Never advance the Intensity Control so far that an excessively bright spot appears. Bright spots imply burning of the screen. A sharp focused spot of high intensity great brightness) should never be allowed to remain fixed in one position on the screen for any length of time as damage to the screen may occur.

- Adjust orizontal and Vertical Centering Controls.
- Adjust the focus to give a sharp trace.
- Set trigger to internal level to auto.

MEASUREMENT PROCEDURES

The following procedures should be followed

I. Set the signal generator to a frequency of 1000 cycles per second after the ON state.

II. Connect the output from the generator to the vertical input of the oscilloscope.

III. Establish a steady trace of this input signal on the scope.

IV. Adjust (play with) all of the scope and signal generator controls until you become familiar with the functions of each. The purpose for such "playing" is to allow the student to become so familiar with the oscilloscope that it becomes an aid (tool) in making measurements in other experiments and not as a formidable obstacle.

V. Note: If the vertical gain is set too low, it may not be possible to obtain a steady trace.

(a) Measurements of Voltage

The signal generator is used to produce a 1000 hertz sine wave.

- The AC voltmeter and the leads to the vertical input of the oscilloscope are connected across the generator's output.
- By adjusting the Horizontal Sweep time/cm and trigger, a steady trace of the sine wave may be displayed on the screen. The trace represents a plot of voltage vs. time, where the vertical deflection of the trace about the line of symmetry CD is proportional to the magnitude of the voltage at any instant of time as shown below.
- To determine the size of the voltage signal appearing at the output of terminals of the signal generator, an AC (Alternating Current) voltmeter is connected in parallel across these terminals as shown in figure above(Fig. 4a). The AC voltmeter is designed to read the dc "effective value" of the voltage. This effective value is also known as the "Root Mean Square value" (RMS) value of the voltage.
- The peak or maximum voltage seen on the scope face is $\mathbf{V_m}$ volts and is represented by the distance from the symmetry line CD to the maximum deflection. The relationship between the magnitude of the peak voltage displayed on the scope and the effective or RMS voltage (V_{RMS}) read on the AC voltmeter is;

$\mathbf{V_{RMS} = 0.707\ V_m}$ (for a sine or cosine wave). Thus;

$$V_m = \frac{V_{RMS}}{0.707}$$

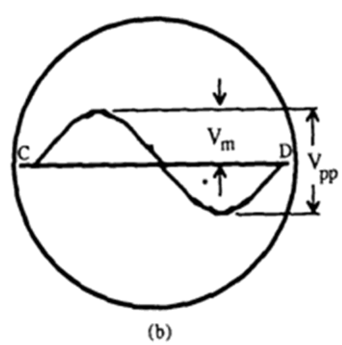
- Agreement is expected between the voltage reading of the multimeter and that of the oscilloscope. For a symmetric wave (whether sine or cosine wave) the value of V_m may be taken as 1/2 the peak to peak signal V_{pp}.

- The variable sensitivity control a signal may be used to adjust the display to fill a convenient range of the scope face. In this position, the trace is no longer calibrated so that you cannot just read the size of the signal by counting the number of divisions and multiplying by the scale factor. However, you can figure out what the new calibration is use it as long as the variable control remains unchanged.

(b) Frequency Measurements:

If the time base (i.e. sweep) is calibrated, such measurements as pulse duration or signal period can be made. Frequencies can then be determined as reciprocal of the periods.

- Set the oscillator to 1000 Hz. Display the signal on the CRO and measure the period of the oscillations. Use the horizontal distance between two points such as C to D in Fig. below.



I. (b) Trace seen on scope.

Fig18 measurement of voltage

- Set the horizontal gain so that only one complete wave form is displayed.
- Then reset the horizontal until 5 waves are seen. Keep the time base control in a calibrated position.

✓ Measure the distance (and hence time) for 5 complete cycles and calculate the frequency from this measurement.

✓ Compare you result with the value determined above.

✓ Repeat your measurements for other frequencies of 150 Hz, 5 kHz, 50 kHz as set on the signal generator.

Safety checklist

The fundamentals of electrical safety can be overlooked, especially by seasoned electricians. It's worth reviewing a few safety tips, both for the novice electrician and the veteran:

- Use a meter that meets accepted safety standards for the environment in which it will be used.
- Use a meter with fused current inputs and be sure to check the fuses before making current measurements.
- Inspect test leads for physical damage before making a measurement.
- Use the meter to check continuity of the test leads.
- Use test leads that have shrouded connectors and finger guards.
- Use meters with recessed input jacks.
- Select the proper function and range for your measurement.
- Be certain the meter is in good operating condition.
- Follow all equipment safety procedures.
- Always disconnect the "hot" (red) test lead first.
- Don't work alone.
- Use a meter that has overload protection on the ohms function.

- When measuring current without a current clamp, turn the power off before connecting into the circuit.
- Be aware of high-current and high-voltage situations and use the appropriate equipment, such as high-voltage probes and high-current clamps.

Various sensors can be attached to (or included in) multimeters to take measurements such as:

- light level
- sound pressure level
- acidity/alkalinity(pH)
- relative humidity
- very small current flow (down to nanoamps with some adapters)
- very small resistances (down to micro ohms for some adapters)
- large currents – adapters are available which use inductance (AC current only) or Hall effect sensors (both AC and DC current), usually through insulated clamp jaws to avoid direct contact with high current capacity circuits which can be dangerous, to the meter and to the operator

Signal generator

Signal generators come in various forms able to produce a variety of waveforms for different test applications. Some of these test instruments address the RF testing arena, whilst others are used for audio testing, possibly as a sine wave generator, etc and others for providing pulses, possibly for exciting digital circuits. There are thousands of different applications for signal generators.

However they differ from the measuring test instruments like oscilloscope, digital multimeters, spectrum analyzers, etc in that rather than measuring a signal, they generate a signal to be applied to a unit under test.

A signal generator is an electronic device that generates repeating or non-repeating electronic signals in either the analog or the digital domain. It is generally used in designing, testing, troubleshooting, and repairing electronic or electroacoustic devices, though it often has artistic uses as well. There are many different types of signal generators with different purposes and applications and at varying levels of expense. These types include function generators , RF and microwave signal generators , pitch generators , arbitrary waveform generators , digital pattern generators and frequency generators . In general, no device is suitable for all possible applications.

Fig 18 signal generator

A function generator is a device which produces simple repetitive waveforms. Such devices contain an electronic oscillator , a circuit that is capable of creating a repetitive waveform (Modern devices may use digital signal processing to synthesize waveforms, followed by a digital to analog converter , or DAC, to produce an analog output). The most common waveform is a sine wave, but saw tooth , step (pulse), square , and triangular waveform oscillators are commonly available as are arbitrary waveform generators (AWGs). If the oscillator operates above the audio frequency range (>20 kHz), the generator will often include some sort of modulation function such as amplitude modulation (AM), frequency modulation (FM), or phase modulation (PM) as well as a second oscillator that provides an audio frequency modulation waveform.

Low voltage power supply (DC)

A power supply is an electronic device that supplies electric energy to an electrical load. The primary function of a power supply is to convert one form of electrical energy to another. As a result, power supplies are sometimes referred to as electric power converters.

Typical Applications

The stabilized DC section comes with an adjustable current limiter - protecting your equipment and useful as a constant current source for low impedance loads

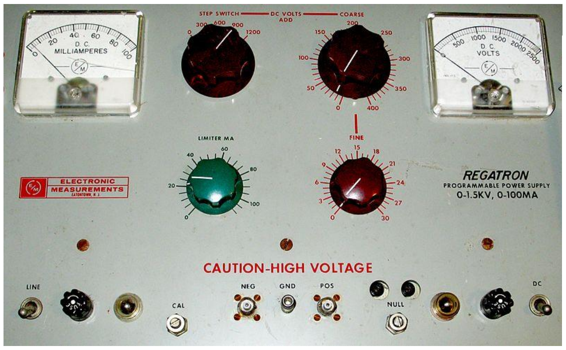


Fig19 stabilized DC power supply

Computers (PC/lap)/Programming console

A console application is a computer program designed to be used via a text-only computer interface, such as a text terminal, the command line interface of some operating systems (Unix , DOS , etc.) or the text-based interface included with most Graphical User Interface (GUI) operating systems, such as the Win32 console in Microsoft Windows , the Terminal in Mac OS X, and xterm in Unix. A user typically interacts with a console application using only a keyboard and display screen , as opposed to GUI applications, which normally require the use of a mouse or other pointing device. Many console applications such as command line interpreters are command line tools, but numerous text-based user interface (TUI) programs also exist.

As the speed and ease-of-use of GUIs applications have improved over time, the use of console applications has greatly diminished, but not disappeared. Some users simply prefer console based applications, while some organizations still rely on existing console applications to handle key data processing tasks.

The ability to create console applications is kept as a feature of modern programming environments such as Visual Studio and the .NET Framework on Microsoft Windows because it greatly simplifies the learning process of a new programming language by removing the complexity of a graphical user interface (see an example in the C# article).

For data processing tasks and computer administration, these programming environments represent the next level of operating system or data processing control after scripting . If an application is only going to be run by the original programmer and/or a few colleagues, there may be no need for a pretty graphical user interface, leaving the application leaner, faster and easier to maintain.

Console-based applications include Alpine (an e-mail client), cmus (an audio player), Irssi (an IRC client), Lynx (a web browser), Mid night. Commander (a file manager), Music on Console (an audio player), Mutt (an e-mail client), nano (a text editor), ne (a text editor), news beuter (an RSS reader), and ranger (a file manager).

Self-Check 3	Written Test

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

Matching

______1. Light Sensor	A. Light detector using LDR
_____2.smoke sensor	b. Smoke detector alarm circuit
______3. Alcohol sensor –	c. How to make alcohol breathalyzer circuit?
_______4. Touch sensor	d. Touch dimmer switch circuit using Arduino
_______5. Color sensor	e. Arduino based color detector
_________6.humidity sensor	f. Dht11 humidity sensor on arduino

. Answer the following question!

Note: Satisfactory rating 7 and 12 points Unsatisfactory below 7 and 12 points

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

Score = ____________
Rating: _____________

Answer Sheet

Name: ___________________________ Date: __________________

Information Sheet 4- Checking for correct operation and safety

4.1 Checking for correct operation and safety

Equipment maintenance and checks for safety

A maintenance schedule should be in place to ensure that you maintain your equipment regularly. You should check equipment as often as suggested by the manufacturer or more often if indicated by the risk assessment. Any daily checks should be undertaken as recommended by the manufacturer. This will help prevent problems such as blockages, leaks or breakdowns, which can increase risks.

You'll also need to maintain safety devices around the equipment such as guards, alarms, safety cages and warning signs.

The duty to maintain work equipment and take measures to manage the risks from maintenance (Provision and Use of Work Equipment Regulations) builds on the general duties of the Health and Safety at Work Act, which requires work equipment to be maintained so that it is safe, and work to be undertaken safely, so far as reasonably practicable.

If you use heat-producing equipment you should regularly check the environment around it. You must keep floors clear. There must be adequate ventilation at all times. You also need to remove all combustible materials from the area and regularly maintain and check fire detectors.

Equipment safely can be checked by:-

If any equipment is to be checked or repaired, it should always be turned off and isolated so no one can start it in error.

Most equipment now comes with guidelines for maintenance. This includes advice on how to carry out equipment checks safely.

Many businesses use documented procedures for maintenance and repair work, such as a permit to work scheme. You can also use warning signs to remind workers that equipment is temporarily out of use. You could also user a lock out system. This means the person doing the maintenance work has a key that prevents the equipment starting up while they work on it.

Inspection of work equipment

The purpose of an inspection is to identify whether work equipment can be operated, adjusted and maintained safely, with any deterioration detected and remedied before it results in a health and safety risk. Not all work equipment needs formal inspection to ensure safety and, in many cases, a quick visual check before use will be sufficient. However, inspection is necessary for any equipment where significant risks to health and safety may arise from incorrect installation, reinstallation, deterioration or any other circumstances. The need for inspection and inspection frequencies should be determined through risk assessment.

What you must do

You should inspect work equipment if your risk assessment identifies any significant risk (for example, of major injury) to operators and others from the equipment's installation or use. The result of the inspection should be recorded and this record should be kept at least until the next inspection of that equipment. Records do not have to be made in writing but, if kept in another form (eg on a computer), these should be held securely and made available upon request by any enforcing authority.

Work equipment that requires inspection should not be used, unless you know the inspection has taken place. Where it leaves your undertaking, or is obtained from another (eg a hire company) it should be accompanied by physical evidence of the last inspection, such as an inspection report or, for smaller items of equipment, some form of tagging, colour coding or labelling system.

What you should know

PUWER regulation 6 specifies the circumstances where inspection is required to ensure healthy and safe conditions are maintained:

- where the safety of work equipment depends on the installation conditions, it should be inspected after installation and before first use, and after reassembly at any new site / location
- at suitable intervals, where work equipment is exposed to conditions causing deterioration liable to result in dangerous situations
- each time exceptional circumstances (eg major modifications, known or suspected serious damage, substantial change in the nature of use) are liable to have jeopardized the safety of the work equipment

An inspection should concentrate on those safety-related parts which are necessary for the safe operation of work equipment and, in some cases, this may require testing or dismantling. However, not all safety-critical features on a particular item of work equipment may require inspection at the same intervals.

An inspection can vary in its extent, as the following demonstrate:

- quick checks before use (eg electric cable condition on hand-held power tools, functional testing of brakes, lights on mobile machinery)
- weekly checks (eg presence of guarding, function of safety devices, tyre pressures, and the condition of windows, mirrors and CCTV on mobile plant)
- more extensive examinations, undertaken every few months or longer (eg general condition of a ladder, close examination of a safety harness, portable appliance testing)

Records are not normally required to be made for the simplest pre-use checks.

The use of checklists can assist but these, and the records made, should be tailored to the particular type of work equipment to minimize the burden to what is strictly necessary for safety. Requiring too much detail too often can lead to inspection activity becoming burdensome with the risk of a superficial 'tick box' approach or even, in some cases, the inspection activity ceasing altogether. You only need to inspect what is necessary for safety.

When should work equipment that needs inspection be re-inspected?

The frequency of inspection may vary, depending on environmental conditions (eg equipment subject to harsh outdoor conditions is likely to need more frequent inspections than if used in an indoor environment).

The frequency of inspection should be determined through risk assessment, taking account of the manufacturer's recommendations, industry advice and your own experience. It may be appropriate to review the frequency of inspection in the light of your experience. Intervals between inspections can be increased if the inspection history shows negligible deterioration, or shortened where experience shows this is necessary to prevent danger.

Who should carry out the inspection of work equipment?

Equipment can be inspected by anyone who has sufficient knowledge and experience of it to enable them to know:

- what to look at
- what to look for
- what to do if they find a problem

The necessary level of competence will vary for inspections, according to the type of equipment and how / where it is used. The nature of these inspections does not have to be determined by the same person who undertakes them, provided the person determining them is competent. This can often be done in-house by experienced staff, taking account of:

- the manufacturer's recommendations
- industry advice
- their own experience of the equipment, its use, the particular factors of the workplace and the people using the work equipment

Self-Check 4	Written Test

Directions: - For the following questions, choose the correct answer from the given alternatives and write the letter of your choice on the answer sheet.

Answer the following question as directed below

1. The purpose of an inspection is:
   A. To identify whether work equipment, tools and testing devices can be operated safely
   B. To identify whether work equipment, tools and testing devices can be adjusted safely
   C. To identify whether work equipment, tools and testing devices can be maintained safely.
   D. All of the above
2. Equipment can be inspected by anyone who has sufficient knowledge and experience to:
   A. Enable what to look at
   B. Enable what to look for Enable
   C. Enable what to do if they find a problem
   D. .All of the above
   E. None of the above
3. One of the followings is NOT correct statement about inspection:
   A. Work equipment that requires inspection should not be used
   B. Inspection is done when at intervals, where work equipment is exposed to conditions causing
   C. The frequency of inspection should be determined as the result of risk assessment.

D. .All of the above

E. None of the above

Answer the following question!

Note: Satisfactory rating 4 and 6 points   Unsatisfactory - below 4and 6 points

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

Answer Sheet

Score = ___________

Rating: ____________

4. Name: _________________________ Date: _______________

Information Sheet 5 - Obtaining materials and components necessary to complete the work.

5.1 Obtaining materials and components necessary to complete the work.

Materials and components Includes the following but not limited to:

Wires

A **wire** is a single, usually cylindrical, flexible strand or rod of metal. Wires are used to bear mechanical loads or electricity and telecommunications signals. Wire is commonly formed by drawing the metal through a hole in a die or draw plate. Wire gauges come in various standard sizes, as expressed in terms of a gauge number.

The term wire is also used more loosely to refer to a bundle of such strands, as in "multistranded wire", which is more correctly termed a wire rope in mechanics, or a cable in electricity.

Wire comes in solid core, stranded, or braided forms. Although usually circular in cross-section, wire can be made in square, hexagonal, flattened rectangular, or other cross-sections, either for decorative purposes, or for technical purposes such as high-efficiency voice coils in loudspeakers. Edge-wound springs, such as the Slinky toy, are made of special flattened wire.

Forms of wire

Solid wire

Solid wire, also called solid-core or single-strand wire, consists of one piece of metal wire. Solid wire is useful for wiring breadboards. Solid wire is cheaper to manufacture than stranded wire and is used where there is little need for flexibility in the wire. Solid wire also provides mechanical ruggedness; and, because it has relatively less surface area which is exposed to attack by corrosives, protection against the environment.

Stranded wire

Stranded wire is composed of a number of small wires bundled or wrapped together to form a larger conductor. Stranded wire is more flexible than solid wire of the same total cross-sectional area. Stranded wire tends to be a better conductor than solid wire because the individual wires collectively comprise a greater surface area.

Stranded wire is used when higher resistance to metal fatigue is required. Such situations include connections between circuit boards in multi-printed-circuit-board devices, where the rigidity of solid wire would produce too much stress as a result of movement during assembly or servicing; A.C. line cords for appliances; musical instrument cables; computer mouse cables; welding electrode cables; control cables connecting moving machine parts; mining machine cables; trailing machine cables; and numerous oth

Braided wire

A braided wire is composed of a number of small strands of wire braided together. Similar to stranded wires, braided wires are better conductors than solid wires. Braided wires do not break easily when flexed. Braided wires are often suitable as an electromagnetic shield in noise-reduction cables.

Varieties

Hook-up wire is small-to-medium gauge, solid or stranded, insulated wire, used for making internal connections inside electrical or electronic devices. It is often tinplated to improve solderability.

Wire bonding is the application of microscopic wires for making electrical connections inside semiconductor components and integrated circuits.

Magnet wire is solid wire, usually copper, which, to allow closer winding when making electromagnetic coils, is insulated only with varnish, rather than the thicker plastic or other insulation commonly used on electrical wire. It is used for the winding of motors, transformers, inductors, generators, speaker coils, etc.

Coaxial cable is a cable consisting of an inner conductor, surrounded by a tubular insulating layer typically made from a flexible material with a high dielectric constant, all of which is then surrounded by another conductive layer (typically of fine woven wire for flexibility, or of a thin metallic foil), and then finally covered again with a thin insulating layer on the outside. The term coaxial comes from the inner conductor and the outer shield sharing the same geometric axis. Coaxial cables are often used as a transmission line for radio frequency signals.

Speaker wire is used to make a low-resistance electrical connection between loudspeakers and audio amplifiers. Some high-end modern speaker wire consists of multiple electrical conductors individually insulated by plastic, similar to Litz wire.

Resistance wire is wire with higher than normal resistivity, often used for heating elements or for making wire-wound resistors. Nichrome wire is the most common type.

Terminal blocks or Barrier Strip

A terminal block is a screw-type electrical connector where the wires are clamped down to the metal part by a screw. It is a connector which allows more than one circuit to connect to another circuit. It often contains two long aluminum or copper strips that are designed to connect different components. These strips create a bus bar for power distribution that is sent to the connected components. A barrier strip is composed of several screw terminals.

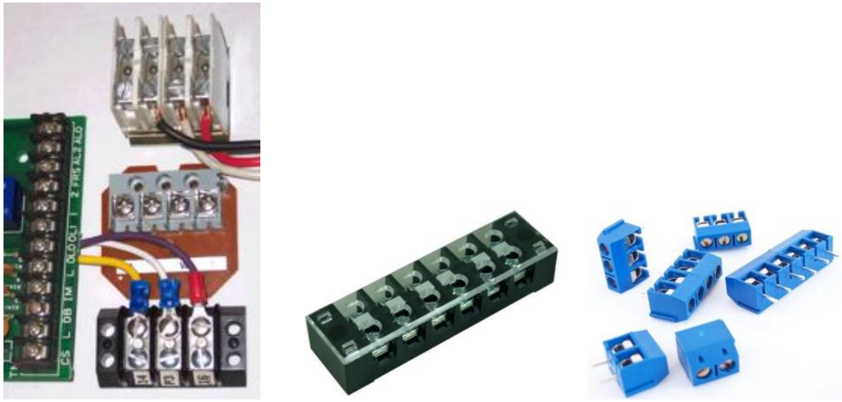


Fig 21 Terminal block

Terminal wire marker

Terminal markers enables you to accomplish virtually any labeling task, on any conductor connector. Whether this involves multi-digit labelling, ready-to-use markers with standard print or customized labeling, white or colour markers or group designations at the clamping points our comprehensive product portfolio is the easy, quick and clear answer to every marking task.

Fig 22 terminal wire marker

Limit switches

In electrical engineering a limit switch is a switch operated by the motion of a machine part or presence of an object.

They are used for controlling machinery as part of a control system, as a safety interlocks, or to count objects passing a point. A limit switch is an electromechanical device that consists of an actuator mechanically linked to a set of contacts. When an object comes into contact with the actuator, the device operates the contacts to make or break an electrical connection.

Limit switches are used in a variety of applications and environments because of their ruggedness, ease of installation, and reliability of operation. They can determine the presence or absence, passing, positioning, and end of travel of an object. They were first used to define the limit of travel of an object; hence the name "Limit Switch".

Fig 23 limit switch

Standardized limit switches are industrial control components manufactured with a variety of operator types, including lever, roller plunger, and whisker type. Limit switches may be directly mechanically operated by the motion of the operating lever. A reed switch may be used to indicate proximity of a magnet mounted on some moving part.

Proximity switches operate by the disturbance of an electromagnetic field, by capacitance, or by sensing a magnetic field.

Rarely, a final operating device such as a lamp or solenoid valve will be directly controlled by the contacts of an industrial limit switch, but more typically the limit switch will be wired through a control relay , a motor contactor control circuit, or as an input to a programmable logic controller .

Different Kinds of Limit Switches Used in Conveyor Belts

While conveyor belts can tremendously increase efficiency, they are prone to jamming from over-loading unless the correct safety measures are put in place.

Limit switches help prevent this by measuring the height or number of individual products passing through the conveyor system. In case the switch senses an object that may cause an obstruction, it shuts the system down to prevent damage or spillage. Depending on the environment and purpose, there are a variety of limit switches which can be used in conveyor systems:

Heavy Duty Limit Switches – Heavy duty limit switches are frequently installed on conveyor systems which are located in harsh environments, both indoors and outdoors. They are very reliable for indicating the position of materials to the system controls.

Applications – Based on the configuration, heavy duty limit switches can be used for counting individual items travelling on the conveyor, or even for ensuring that each one is in the right position and correctly aligned.

Safety Switches – Automated safety measures are essential for safe operations, but manually operated safety switches are also equally important. Safety switches use a cable-pull system, which is composed of a snap-action switch linked to a cable with a grip at the end.

Applications – Safety switches are extremely safe to use, providing an extremely reliable and highly visible device to immediately stop a conveyor. In case a situation arises where operators need to quickly stop the conveyor, they can simply yank the cable pull.

Hazardous Location Limit Switches – Conveyors are also quite adaptable to different environments, including some very harsh ones. Hazardous location limit switches are similar to heavy-duty ones, except they are housed in enclosures which are sealed and rated for use in different hazardous locations. These could be above-ground, outdoors, or in environments that are prone to explosions, such as fuel or grain handling.

Applications – Hazardous location limit switches are used in applications where they may be exposed to hazardous environments, or potentially dangerous situations which could trigger an explosion from electrical discharges, sparks and other external factors.

Safety and Hazardous Location Switches – Conveyor belts in hazardous locations are often automated, with a centralized control system, but some of them do require human intervention. Safety and hazardous location switches are similar to safety switches , but they are rated for use in hazardous locations.

Applications – Safety and hazardous location switches are used in environments where suspended particles, gas or other compounds are present in the surroundings. These switches can be tripped in case a potential for danger is spotted, without increasing the risks of an explosion or other disaster resulting from operating the switch

Calibrators

A calibrator is equipment used to adjust a instrument accuracy, often associated with a specific application: temperature, pressure, weight.

Flow sensing This is the use of pressure sensors in conjunction with the venturi effect to measure flow. Differential pressure ismeasured between two segments of a venturi tube that have a different aperture. The pressure difference between the two segments is directly proportional to the flow rate through the venturi tube. A low pressure sensor is almost alwaysrequired as the pressure difference is relatively small.**Level / depth sensing**A pressure sensor may also be used to calculate the level of a fluid. This technique is commonly employed to measurethe depth of a submerged body (such as a diver or submarine), or level of contents in a tank (such as in a water tower).For most practical purposes, fluid level is directly proportional to pressure. In the case of fresh water where the contentsare under atmospheric pressure, 1psi = 27.7 inH20 / 1Pa = 9.81 mmH20. The basic equation for such a measurement iswhere, P = pressure, ρ = density of the fluid, g = standard gravity, h = height of fluid column above pressure sensor Leak testing

A pressure sensor may be used to sense the decay of pressure due to a system leak. This is commonly done by either comparison to a known leak using differential pressure, or by means of utilizing the pressure sensor to measure pressure change over time. Ratio metric Correction of Transducer Output Piezo resistive transducers configured as Wheatstone bridges often exhibit ratio metric behavior with respect not only to the measured pressure, but also the transducer supply voltage

Flow measurement is the quantification of bulk fluid movement. Flow can be measured in a variety of ways. The common types of flow meters with industrial applications are listed below:

a. Obstruction type (differential pressure or variable area)
b. Inferential (turbine type)
c. Electromagnetic
d. Positive-displacement flowmeters, which accumulate a fixed volume of fluid and then count the number of times the volume is filled to measure flow.
e. Fluid dynamic (vortex shedding)
f. Anemometer
g. Ultrasonic
h. Mass flowmeter (Coriolis force).

Variable frequency drive

A variable frequency drive (VFD) is a type of motor controller that drives an electric motor by varying the frequency and voltage of its power supply. The VFD also has the capacity to control ramp-up and ramp-down of the motor during start or stop, respectively.

There are many reasons why we may want to adjust this motor speed.
For example, to

- Save energy and improve system efficiency
- Convert power in hybridization applications
- Match the speed of the drive to the process requirements
- Match the torque or power of a drive to the process requirements
  Improve the working environment
  Lower noise levels, for example from fans and pumps
- Reduce mechanical stress on machines to extend their lifetime
  Shave peak consumption to avoid peak-demand prices and reduce the motor size required

The most common uses of a VFD are for control of fans, pumps and compressors, and these applications account for 75% of all drives operating globally.

Advantage of using a VFD

A variable frequency drive can use VFD control to vary the power supplied to match the energy requirement of the driven equipment, and this is how it saves energy or optimizes energy consumption.

The drive can dramatically reduce energy consumption when compared to direct-on-line (DOL) operation, where the motor runs at full speed regardless of the demand. Using a drive, power or fuel savings of 40% are common. The roll-on effect means that use of drives also the reduces NOx emissions and CO2 footprint of the systems in which it's installed. Another use for VFDs is in power conversion for hybrid systems using battery storage.

Relay

Types of Relays

There are two basic classifications of relays: Electromechanical and Solid State. Electromechanical relays have moving parts, whereas solid state relays have no moving parts.

Advantages of Electromechanical relays include lower cost, no heat sink is required, multiple poles are available, and they can switch AC or DC with equal ease.

Electromechanical Relays General Purpose Relay: The general-purpose relay is rated by the amount of current its switch contacts can handle. Most versions of the general-purpose relay have one to eight poles and can be single or double throw. These are found in computers, copy machines, and other consumer electronic equipment and appliances. Power Relay: The power relay is capable of handling larger power loads – 10-50 amperes or more. They are usually single-pole or double-pole units. Contactor: A special type of high power relay, it’s used mainly to control high voltages and currents in industrial electrical applications. Because of these high power requirements, contactors always have double-make contacts.

Time-Delay Relay: The contacts might not open or close until some time interval after the coil has been energized. This is called delay-on-operate. Delay-on-release means that the contacts will remain in their actuated position until some interval after the power has been removed from the coil. A third delay is called interval timing. Contacts revert to their alternate position at a specific interval of time after the coil has been energized. The timing of these actions may be a fixed parameter of the relay, or adjusted by a knob on the relay itself, or remotely adjusted through an external circuit.

Solid State Relays

These active semiconductor devices use light instead of magnetism to actuate a switch. The light comes from an LED, or light emitting diode. When control power is applied to the device’s output, the light General Purpose Relay is turned on and shines across an open space. On the load side of this space, a part of the device senses the presence of the light, and triggers a solid state switch that either opens or closes the circuit under control. Often, solid state relays are used where the circuit under control must be protected from the introduction of electrical noises. Advantages of Solid State Relays include low EMI/RFI, long life, no moving parts, no contact bounce, and fast response. The drawback to using a solid state relay is that it can only accomplish single pole switching.

Pneumatic relay

A pneumatic relay is a pneumatic amplifier used to take a signal from the flapper and nozzle and boost it to the standard 3 psig to 15 psig transmission signal range. The output from the pneumatic relay is the transmission signal. The relay has a 20 psig air ply that enters the supply chamber. The opening between the supply chamber and the output signal chamber has an air supply valve plug that limits the flow between chambers.

The size of the opening is controlled by a relay vent plug that is connected to a diaphragm that moves in response to the air from the flapper and nozzle. A feedback bellows using the pneumatic transmission signal is connected to the measurement device linkages to balance the forces and stabilize the pneumatic output. Pneumatic controllers use these same basic elements plus other mechanisms to provide the control functions

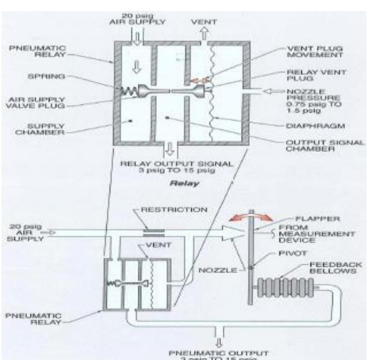


Fig 24Pneumatic relay

A pneumatic receiver element is a simple spring-opposed bellows connected to indicators, recorders, controllers, control valves, or switches where the change in position of the movable end of the bellows is proportional to the pneumatic pressure.

Multiple receiver elements can be connected to the same transmission source, slows down the response of the systems.

Electrical Relay

Electrical relays and contactors use a low level control signal to switch a much higher voltage or current supply using a numers of different contact arrangements

The Electromechanical Relay

The term Relay generally refers to a device that provides an electrical connection between two or more points in response to the application of a control signal. The most common and widely used type of electrical relay is the electromechanical relay or EMR.

Fig 25 An Electrical Relay

The most fundamental control of any equipment is the ability to turn it “ON” and “OFF”. The easiest way to do this is using switches to interrupt the electrical supply. Although switches can be used to control something, they have their disadvantages. The biggest one is that they have to be manually (physically) turned “ON” or “OFF”. Also, they are relatively large, slow and only switch small electrical currents.

Electrical Relays however, are basically electrically operated switches that come in many shapes, sizes and power ratings suitable for all types of applications. Relays can also have single or multiple contacts within a single package with the larger power relays used for mains voltage or high current switching applications being called "Contactors".

electromechanical relays are electro-magnetic devices that convert a magnetic flux generated by the application of a low voltage electrical control signal either AC or DC across the relay terminals, into a pulling mechanical force which operates the electrical contacts within the relay. The most common form of electromechanical relay consist of an energizing coil called the "primary circuit" wound around a permeable iron core.

This iron core has both a fixed portion called the yoke, and a moveable spring loaded part called the armature, that completes the magnetic field circuit by closing the air gap between the fixed electrical coil and the moveable armature. The armature is hinged or pivoted allowing it to freely move within the generated magnetic field closing the electrical contacts that are attached to it. Connected between the yoke and armature is normally a spring (or springs) for the return stroke to "reset" the contacts back to their initial rest position when the relay coil is in the "de-energized" condition, i.e. turned "OFF".

Electromechanical Relay Construction

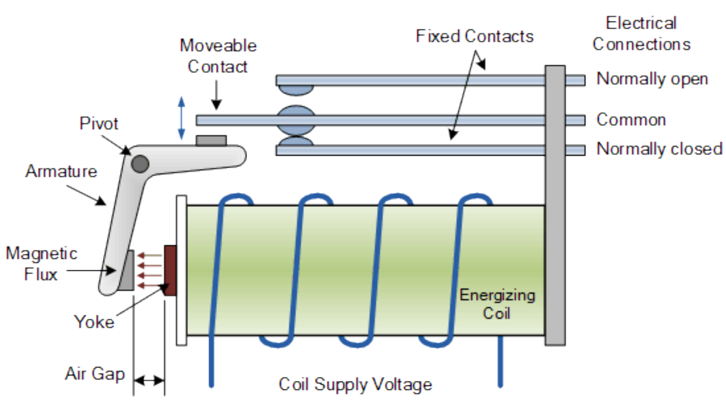


Fig 26 Electromechanical Relay Construction

In our simple relay above, we have two sets of electrically conductive contacts. Relays may be "Normally Open", or "Normally Closed". One pair of contacts are classed as **Normally Open, (NO)** or make contacts and another set which are classed as

Normally Closed, (NC) or break contacts. In the normally open position, the contacts are closed only when the field current is "ON" and the switch contacts are pulled towards the inductive coil.

In the normally closed position, the contacts are permanently closed when the field current is "OFF" as the switch contacts return to their normal position. These terms Normally Open, Normally Closed or Make and Break Contacts refer to the state of the electrical contacts when the relay coil is "de-energized", i.e, no supply voltage connected to the relay coil. Contact elements may be of single or double make or break designs. An example of this arrangement is given below.

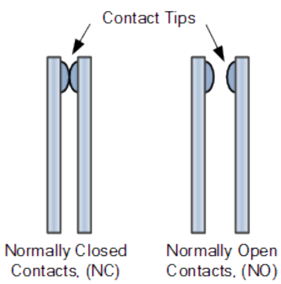


Fig contacts of relay

The relays contacts are electrically conductive pieces of metal which touch together completing a circuit and allow the circuit current to flow, just like a switch. When the contacts are open the resistance between the contacts is very high in the Mega-Ohms, producing an open circuit condition and no circuit current flows.

When the contacts are closed the contact resistance should be zero, a short circuit, but this is not always the case. All relay contacts have a certain amount of "contact resistance" when they are closed and this is called the "On-Resistance", similar to FET's.

With a new relay and contacts this ON-resistance will be very small, generally less than 0.2Ωbecause the tips are new and clean, but over time the tip resistance will increase.

For example. If the contacts are passing a load current of say 10A, then the voltage drop across the contacts using Ohms Law is 0.2 x 10 = 2 volts, which if the supply voltage is say 12 volts then the load voltage will be only 10 volts (12 – 2). As the contact tips begin to wear, and if they are not properly protected from high inductive or capacitive loads, they will start to show signs of arcing damage as the circuit current still wants to flow as the contacts begin to open when the relay coil is de-energized.

This arcing or sparking across the contacts will cause the contact resistance of the tips to increase further as the contact tips become damaged. If allowed to continue the contact tips may become so burnt and damaged to the point were they are physically closed but do not pass any or very little current.

If this arcing damage becomes to severe the contacts will eventually "weld" together producing a short circuit condition and possible damage to the circuit they are controlling. If now the contact resistance has increased due to arcing to say 1Ω the volt drop across the contacts for the same load current increases to 1 x 10 = 10 volts dc. This high voltage drop across the contacts may be unacceptable for the load circuit especially if operating at 12 or even 24 volts, then the faulty relay will have to be replaced.

To reduce the effects of contact arcing and high "On-resistances", modern contact tips are made of, or coated with, a variety of silver based alloys to extend their life span as given in the following table.

Electrical Relay Contact Tip Materials

Ag (fine silver)

1. Electrical and thermal conductivity are the highest of all the metals.

2. Exhibits low contact resistance, is inexpensive and widely used.

3. Contacts tarnish easily through sulphurisation influence.

AgCu (silver copper)

1. Known as “Hard silver” contacts and have better wear resistance and less tendency to arc and weld, but slightly higher contact resistance.

AgCdO (silver cadmium oxide)

1. Very little tendency to arc and weld, good wear resistance and arc extinguishing properties.

AgW (silver tungsten)

1. Hardness and melting point are high, arc resistance is excellent.

2. Not a precious metal.

3. High contact pressure is required to reduce resistance.

4. Contact resistance is relatively high, and resistance to corrosion is poor.

AgNi (silver nickel)

1. Equals the electrical conductivity of silver, excellent arc resistance.

AgPd (silver palladium)

1. Low contact wear, greater hardness.

2. Expensive.

Platinum, Gold and Silver Alloys

1. Excellent corrosion resistance, used mainly for low-current circuits.

Extending the life of relay tips by reducing the amount of arcing generated as they open is achieved by connecting a Resistor-Capacitor network called an RC Snubber Network electrically in parallel with an electrical relay contact tips. The voltage peak, which occurs at the instant the contacts open, will be safely short circuited by the RC network, thus suppressing any arc generated at the contact tips. For example.

Electrical Relay Snubber Circuit

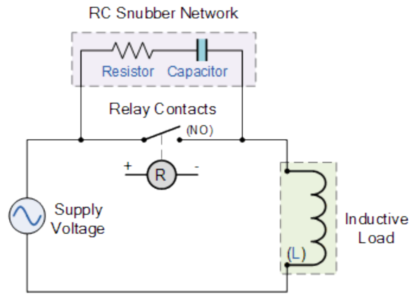


Fig 27 Electrical Relay Snubber Circuit

Electrical Relay Contact Types.

As well as the standard descriptions of Normally Open, (NO) and Normally Closed, (NC) used to describe how the relays contacts are connected, relay contact arrangements can also be classed by their actions. Electrical relays can be made up of one or more individual switch contacts with each "contact" being referred to as a "pole". Each one of these contacts or poles can be connected or "thrown" together by energizing the relays coil and this gives rise to the description of the contact types as being:

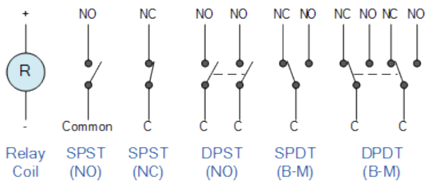
- SPST – Single Pole Single Throw
- SPDT – Single Pole Double Throw
- DPST – Double Pole Single Throw
- DPDT – Double Pole Double Throw

with the action of the contacts being described as "Make" (M) or "Break" (B). Then a simple relay with one set of contacts as shown above can have a contact description of:

"Single Pole Double Throw – (Break before Make)", or SPDT – (B-M)

Examples of just some of the more common diagrams used for electrical relay contact types to identify relays in circuit or schematic diagrams is given below but there are many more possible configurations.

Electrical Relay Contact Configurations



- Where:
- C is the Common terminal
- NO is the Normally Open contact
- NC is the Normally Closed contact

Electromechanical relays are also denoted by the combinations of their contacts or switching elements and the number of contacts combined within a single relay. For example, a contact which is normally open in the de-energised position of the relay is called a "Form A contact" or make contact. Whereas a contact which is normally closed in the de-energised position of the relay is called a "Form B contact" or break contact.

When both a make and a break set of contact elements are present at the same time so that the two contacts are electrically connected to produce a common point (identified by three connections), the set of contacts are referred to as "Form C contacts" or change-over contacts. If no electrical connection exists between the make and break contacts it is referred to as a double change-over contact.

One of the more important parts of any electrical relay is its coil. This converts electrical current into an electromagnetic flux which is used to mechanically operate the relays contacts. The main problem with relay coils is that they are "highly inductive loads" as they are made from coils of wire. Any coil of wire has an impedance value made up of resistance (R) and inductance (L) in series (LR Series Circuit).

Servo moter

A **servomotor** is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors.

Servomotors are not a specific class of motor, although the term servomotor is often used to refer to a motor suitable for use in a closed-loop control system.

Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing.

A servomotor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is a signal (either analogue or digital) representing the position commanded for the output shaft.

The very simplest servomotors use position-only sensing via a potentiometer and bang-bang control of their motor; the motor always rotates at full speed (or is stopped). This type of servomotor is not widely used in industrial motion control, but it forms the basis of the simple and cheap servos used for radio-controlled models.

Fig digital servo motor

DC Servo Motor

The motor which is used as a DC servo motor generally have a separate DC source in the field of winding & armature winding. The control can be archived either by controlling the armature current or field current. Field control includes some particular advantages over armature control. In the same way armature control includes some advantages over field control. Based on the applications the control should be applied to the DC servo motor. DC servo motor provides very accurate and also fast respond to start or stop command signals due to the low armature inductive reactance. DC servo motors are used in similar equipments and computerized numerically controlled machines.

Positional Rotation Servo Motor

Positional rotation servo motor is a most common type of servo motor. The shaft's o/p rotates in about 180o. It includes physical stops located in the gear mechanism to stop turning outside these limits to guard the rotation sensor. These common servos involve in radio controlled water, radio controlled cars, aircraft, robots, toys and many other applications.

Continuous Rotation Servo Motor

Continuous rotation servo motor is quite related to the common positional rotation servo motor, but it can go in any direction indefinitely. The control signal, rather than set the static position of the servo, is understood as the speed and direction of rotation.

The range of potential commands sources the servo to rotate clockwise or anticlockwise as preferred, at changing speed, depending on the command signal. This type of motor is used in a radar dish if you are riding one on a robot or you can use one as a drive motor on a mobile robot.

Linear Servo Motor

Linear servo motor is also similar the positional rotation servo motor is discussed above, but with an extra gears to alter the o/p from circular to back-and-forth. These servo motors are not simple to find, but sometimes you can find them at hobby stores where they are used as actuators in higher model airplanes.

Servo Motor Working

A unique design for servo motors are proposed in controlling the robotics and for control applications. They are basically used to adjust the speed control at high torques and accurate positioning. Parts required are motor position sensor and a highly developed controller. These motors can be categorized according the servo motor controlled by servomechanism. If DC motor is controlled using this mechanism, then it is named as a DC servo motor. Servo motors are available in power ratings from fraction of a watt to 100 watts.The rotor of a servo motor is designed longer in length and smaller in diameter so that it has low inertia. To know more about this, please follow the link: Servo motor working principle and interfacing with 8051 microcontroller

Applications of Servo Motor

The servo motor is small and efficient, but serious to use in some applications like precise position control.This motor is controlled by a pulse width modulator signal. The applications of servo motors mainly involve in computers, robotics, toys, CD/DVD players, etc. These motors are extensively used in those applications where a particular task is to be done frequently in an exact manner.

The servo motor is used in robotics to activate movements, giving the arm to its precise angle.

The Servo motor is used to start, move and stop conveyor belts carrying the product along with many stages. For instance, product labeling, bottling and packaging

The servo motor is built into the camera to correct a lens of the camera to improve out of focus images.

The servo motor is used in robotic vehicle to control the robot wheels, producing plenty torque to move, start and stop the vehicle and control its speed.

The servo motor is used in solar tracking system to correct the angle of the panel so that each solar panel stays to face the sun

The Servo motor is used in metal forming and cutting machines to provide specific motion control for milling machines

The Servo motor is used in Textiles to control spinning and weaving machines, knitting machines and looms

The Servo motor is used in automatic door openers to control the door in public places like supermarkets, hospitals and theatres.

Stepper motor

A stepper motor, also known as step motor or stepping motor, is a brushless DC electric motor that divides a full rotation into a number of equal steps. The motor's position can then be commanded to move and hold at one of these steps without any position sensor for feedback (an open-loop controller), as long as the motor is carefully sized to the application in respect to torque and speed. Switched reluctance motors are very large stepping motors with a reduced pole count, and generally are closed-loop commutated.

The stepper motor is an electromagnetic device that converts digital pulses into mechanical shaft rotation. Advantages of step motors are low cost, high reliability, high torque at low speeds and a simple, rugged construction that operates in almost any environment. The main disadvantages in using a stepper motor is the resonance effect often exhibited at low speeds and decreasing torque with increasing speed.

Stepper motors effectively have multiple "toothed" electromagnets arranged as a stator around a central rotor, a gear-shaped piece of iron. The electromagnets are energized by an external driver circuit or a micro controller

A stepper motor system consists of three basic elements, often combined with some type of user interface (host computer, PLC or dumb terminal): .

Advantages

- Low cost for control achieved

- High torque at startup and low speeds
- Ruggedness
- Simplicity of construction
- Can operate in an open loop control system
- Low maintenance
- Less likely to stall or slip
- Will work in any environment
- Can be used in robotics in a wide scale.
- High reliability
- The rotation angle of the motor is proportional to the input pulse.
- The motor has full torque at standstill (if the windings are energized)

Brushed DC motors rotate continuously when DC voltage is applied to their terminals. The stepper motor is known for its property of converting a train of input pulses (typically square waves) into a precisely defined increment in the shaft's rotational position. Each pulse rotates the shaft through a fixed angle.

Types

There are three main types of stepper motors:

1. Permanent magnet stepper
2. Variable reluctance stepper
3. Hybrid synchronous stepper

Permanent magnet motors use a permanent magnet (PM) in the rotor and operate on the attraction or repulsion between the rotor PM and the stator electromagnets.

Pulses move the rotor in discrete steps, CW or CCW. If left powered at a final step a strong detent remains at that shaft location. This detent has a predictable spring rate and specified torque limit; slippage occurs if the limit is exceeded. If current is removed a lesser detent still remains, therefore holding shaft position against spring or other torque influences. Stepping can then be resumed while reliably being synchronized with control electronics.

Variable reluctance (VR) motors have a plain iron rotor and operate based on the principle that minimum reluctance occurs with minimum gap, hence the rotor points are attracted toward the stator magnet poles. Whereas hybrid synchronous are a combination of the permanent magnet and variable reluctance types, to maximize power in a small size. VR motors do not have power off detents.

Applications

Computer controlled stepper motors are a type of motion-control positioning system. They are typically digitally controlled as part of an open loop system for use in holding or positioning applications.

In the field of lasers and optics they are frequently used in precision positioning equipment such as linear actuators, linear stages, rotation stages, goniometers, and mirror mounts. Other uses are in packaging machinery, and positioning of valve pilot stages for fluid control systems.

Commercially, stepper motors are used in floppy disk drives, flatbed scanners, computer printers, plotters, slot machines, image scanners, compact disc drives, intelligent lighting, camera lenses, CNC machines, and 3D printers.

Sensor and transducer

Sensor:- Any device that is sensitive to a change in the measured phenomenon or characteristic

Transducer:- A device that converts one form energy to another, such as converting pressure to voltage. An element or device that receives information in the form of one quantity and converts it to information in the form of the same or another quantity.

Primary element:- The sensing device that detect the condition of the process variable.

Transducer are devices which convert one type of energy into another, such as electrical energy into light or sound, or creates an electrical output corresponding to some physical parameter

Input Devices or Sensors

- Sensors are “Input” devices which convert one type of energy or quantity into an electrical analogue signal.
- The most common forms of sensors are those that detect Position, Temperature, Light, Pressure and Velocity.
- The simplest of all input devices is the switch or push button.
- Some sensors called “Self-generating” sensors generate output voltages or currents relative to the quantity being measured, such as thermocouples and photo-voltaic solar cells and their output bandwidth equals that of the quantity being measured.
- Some sensors called “Modulating” sensors change their physical properties, such as inductance or resistance relative to the quantity being measured such as inductive sensors, LDR’s and potentiometers and need to be biased to provide an output voltage or current.
- Not all sensors produce a straight linear output and linearisation circuitry may be required.
- Signal conditioning may also be required to provide compatibility between the sensors low output signal and the detection or amplification circuitry.
- Some form of amplification is generally required in order to produce a suitable electrical signal which is capable of being measured.
- Instrumentation type Operational Amplifiers are ideal for signal processing and conditioning of a sensors output signal.

Output Devices or Actuators

- “Output” devices are commonly called Actuators and the simplest of all actuators is the lamp.

- Relays provide good separation of the low voltage electronic control signals and the high power load circuits.
- Relays provide separation of DC and AC circuits (i.e. switching an alternating current path via a DC control signal or vice versa).
- Solid state relays have fast response, long life, no moving parts with no contact arcing or bounce but require heat sinking.
- Solenoids are electromagnetic devices that are used mainly to open or close pneumatic valves, security doors and robot type applications. They are inductive loads so a flywheel diode is required.
- Permanent magnet DC motors are cheaper and smaller than equivalent wound motors as they have no field winding.
- Transistor switches can be used as simple ON/OFF unipolar controllers and pulse width speed control is obtained by varying the duty cycle of the control signal.
- Bi-directional motor control can be achieved by connecting the motor inside a transistor H-bridge.
- Stepper motors can be controlled directly using transistor switching techniques.
- The speed and position of a stepper motor can be accurately controlled using pulses so can operate in an Open-loop mode.
- Microphones are input sound transducers that can detect acoustic waves either in the Infra sound, Audible sound or Ultrasound range generated by a mechanical vibration.
- Loudspeakers, buzzers, horns and sounders are output devices and are used to produce an output sound, note or alarm.

Actuators convert an electrical signal into a corresponding physical quantity such as movement, force, sound etc. An actuator is also classed as a transducer because it changes one type of physical quantity into another and is usually activated or operated by a low voltage command signal. Actuators can be classed as either binary or continuous devices based upon the number of stable states their output has.

Input devices that can be used to detect or “sense” a variety of physical variables and signals and are therefore called **Sensors**. But there are also a variety of electrical and electronic devices which are classed as Output devices used to control or operate some external physical process. These output devices are commonly called **Actuators**.·

Actuators

They’re primarily categorized by their drive mechanism; there are five main types of actuators –

- hydraulic
- pneumatic
- electrical
- Thermal or Magnetic and
- Mechanical.

An actuator is a type of motor that is responsible for moving or controlling a mechanism or system. It is operated by a source of energy, typically electric current, hydraulic fluid pressure, or pneumatic pressure, and converts that energy into motion. An actuator is the mechanism by which a control system acts upon an environment. The control system can be simple (a fixed mechanical or electronic system), software-based (e.g. a printer driver, robot control system), a human, or any other input.

Hydraulic

A hydraulic actuator consists of a cylinder or fluid motor that uses hydraulic power to facilitate mechanical operation. The mechanical motion gives an output in terms of linear, rotary or oscillatory motion. Because liquids are nearly impossible to compress, a hydraulic actuator can exert considerable force. The drawback of this approach is its limited acceleration.

The hydraulic cylinder consists of a hollow cylindrical tube along which a piston can slide. The term single acting is used when the fluid pressure is applied to just one side of the piston. The piston can move in only one direction, a spring being frequently used to give the piston a return stroke. The term double acting is used when pressure is applied on each side of the piston; any difference in pressure between the two side of the piston moves the piston to one side or the other.

Hydraulic rotary actuators are used for high torque, heavy-duty motion applications. They have high force capabilities, high power-per-unit weight and volume, good mechanical stiffness, and high dynamic response. They provide the heft for lifting, turning, indexing, clamping, mixing, bending, testing, and steering applications among others.

Rotary actuators are compact and efficient, and produce high instantaneous torque in either direction. This makes them widely used in precision control systems and in heavy-duty machine tool, mobile, marine and aerospace applications.

Rotary motor actuators are coupled directly to a rotating load and provide good control for acceleration, operating speed,. deceleration, smooth reversals, and positioning.

They allow flexibility in design and eliminate much of the bulk and weight of mechanical and electrical power transmissions.

Because they are fully enclosed, they withstand harsh conditions and are protected from dust, dirt, and moisture.

Pneumatic

Pneumatic rack and pinion actuators for valve controls of water pipes A pneumatic actuator converts energy formed by vacuum or compressed air at high pressure into either linear or rotary motion. Pneumatic energy is desirable for main engine controls because it can quickly respond in starting and stopping as the power source does not need to be stored in reserve for operation. Pneumatic actuators enable large forces to be produced from relatively small pressure changes. These forces are often used with valves to move diaphragms to affect the flow of liquid through the valve. It is responsible for converting pressure into force.

Electric

An electric actuator is powered by a motor that converts electrical energy into mechanical torque. The electrical energy is used to actuate equipment such as multi-turn valves. It is one of the cleanest and most readily available forms of actuator because it does not involve oil. Thermal or magnetic (shape memory alloys)

Actuators which can be actuated by applying thermal or magnetic energy have been used in commercial applications. They tend to be compact, lightweight, economical and with high power density. These actuators use shape memory materials (SMMs), such as shape memory alloys (SMAs) or magnetic shape- memory alloys (MSMAs). Some popular manufacturers of these devices are Finnish Modti Inc. and American Dynalloy.

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Mechanical

A mechanical actuator functions by converting rotary motion into linear motion to execute movement. It involves gears, rails, pulleys, chains and other devices to operate. An example is a rack and pinion.

Pneumatically driven actuators

Although they're not electromechanical devices like the other actuator types, their prevalence in automated equipment makes pneumatic driven versions an important category of linear actuators. Pneumatic actuators can be further divided into two sub-categories: slider-type and rod-type.

In slider-type actuators, the motion is contained within the limits of a housing and the load is mounted to a slider (also referred to as a carriage, saddle, or table). In rod-type actuators, the motion is produced by a rod that extends and retracts from a housing. The load may be mounted to the end of the rod, or the rod can be used to push the load. (Think of pressing or stamping a label onto a carton, or pushing defective products to a diverter lane along a conveyor.)

Slider-type pneumatic actuators can be guided by recirculating or plain bearings, depending on the load they're designed for. Rod-style versions are not typically designed for axial loads, and use simple plain bearings to provide guidance to the rod, without significantly contributing to load-carrying capacity.

Rack-and-pinion driven actuators

For extremely long lengths and robustness against contamination, rack and pinion drives are often the best choice. However, these characteristics make finding a suitable guide system difficult in some applications. For extremely long lengths, joined profiled rails are sometimes used, but when contamination is a significant concern, metal wheels are usually preferred. A unique feature of rack and pinion types is their ability to drive multiple carriages independently. A common application for rack and pinion actuators is the overhead gantry, often found in automotive production.

Linear motor driven actuators

Linear motor actuators are also capable of long travel lengths with multiple carriages, but they're primarily used for high- precision, highly dynamic motion. To complement the strengths of the linear motor, these actuators use high precision profiled rails, crossed roller guides, or even air bearings as their guidance system. Linear motor types can be mounted in an extruded housing or on a machined aluminum plate, but in order to meet the highest travel accuracy specifications, they can also be mounted on a machined steel plate or granite base.

With so many options, choosing the best linear actuator is a complex task, and there's not one "right" way to make a selection. The best place to start, however, is usually with a manufacturer’s sizing software or selection program. Still, the results often include several choices, which can be narrowed down by looking at non-quantitative criteria, such as ease of maintenance, integration with existing components or systems, and space constraints.

Different Types of Sensors

The following is a list of different types of sensors that are commonly used in various applications. All these sensors are used for measuring one of the physical properties like Temperature, Resistance, Capacitance, Conduction, Heat Transfer etc.

- Temperature Sensor
- Proximity Sensor
- Accelerometer
- IR Sensor (Infrared Sensor)
- Pressure Sensor
- Light Sensor
- Ultrasonic Sensor
- Smoke, Gas and Alcohol Sensor
- Touch Sensor
- Color Sensor
- Humidity Sensor
- Tilt Sensor
- Flow and Level Sensor

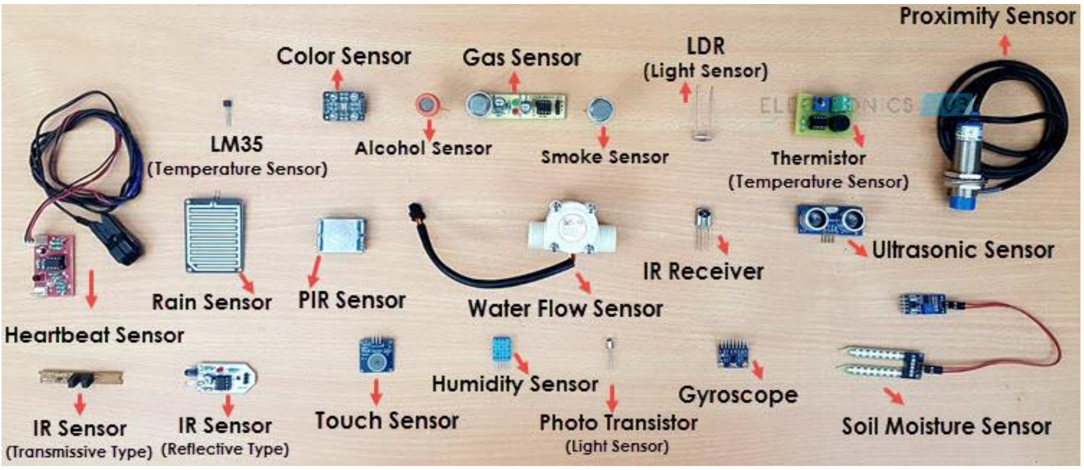

Fig30 different types of sensor

Speed Sensor

Sensors used for detecting speed of an object or vehicle is called as Speed sensor. There are different types of sensors to detect the speed such as Wheel speed sensors, speedometers, LIDAR, ground speed radar, pitometer logs, doppler radar, air speed indicators, pitot tubes and so on.

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Fig 31 speed sensor

Ultrasonic Sensor

An Ultrasonic Sensor is a non-contact type device that can be used to measure distance as well as velocity of an object. An Ultrasonic Sensor works based on the properties of the sound waves with frequency greater than that of the human audible range. The transducer used for converting energy into ultrasound or sound waves with ranges above human hearing range is called an ultrasonic transducer

Fig32 ultrasonic sensor

Using the time of flight of the sound wave, an Ultrasonic Sensor can measure the distance of the object (similar to SONAR). The Doppler Shift property of the sound wave is used to measure the velocity of an object.

Arduino based Range Finder is a simple project using Ultrasonic Sensor: portable ultrasonic range meter.

Application of Ultrasonic Sensor

The distance measurement at inaccessible areas is a typical application of ultrasonic sensors. The circuit consists of an ultrasonic module, LCD display and microcontroller. The ultrasonic module is interfaced with the microcontroller and this ultrasonic transducer consists of a transmitter and receiver.

Motion

Way in which a motion sensor works typically depends on the type of sensor being used, which often depends on the device that uses the sensor. One of the most common types of sensor technology is an active sensor that sends out bursts of energy, which bounces back in a way similar to sonar. There are also passive sensors that do not send out any type of signal, but instead receive energy from their surroundings to detect motion. Some systems can also use a combination of both active and passive technology to create a motion sensor that emits and receives an energy signal.

A motion sensor is an electronic device often part of a larger system, such as a light or camera that detects motion to activate the system. There are two basic types of motion sensors. A motion sensor can also utilize a combination of passive and active technology.

Types of Motion Sensors

Passive Infrared (PIR):- Detects body heat (infrared energy). Passive infrared sensors are the most widely used motion in home security systems. When your system is armed, your motion sensors are activated. Once the sensor warms up, it can detect heat and movement in the surrounding areas, creating a protective "grid." If a moving object blocks too many grid zones and the infrared energy levels change rapidly, the sensors are tripped.

MircoWave (MW)::- Sends out microwave pulses and measures the reflection off a moving object. They cover a larger area than infrared sensors, but they are vulnerable to electrical interference and are more expensive.

Dual Technology Motion Sensors::- Motion sensors can have combined features in an attempt to reduce false alarms. For example, a passive infrared (PIR) sensor could be combined with a microwave sensor. Since each operates in different areas of the spectrum, and one is passive and one is active, Dual Technology motion sensors are not as likely as other types to cause false alarms, because in order for the alarm to be triggered, both sensors have to be tripped. However, this does not mean that they never cause false alarms.

Area Reflective Typ: - Emits infrared rays from an LED. Using the reflection of those rays, the sensor measures the distance to the person or object and detects if the object is within the designated area.

Ultrasonic:: - Sends out pulses of ultrasonic waves and measures the reflection off a moving object.

Vibration::- Detects vibration. These can be purchased or easily made at home. A homemade vibration sensor uses a small mass on a lever, which is activated by a switch to an alarm when it vibrates. Homemade motion sensors can work, but they can also be unreliable.

Wireless Motion Sensors::- Today, most motion sensors are wireless. Wireless sensors are very easy to set up. They do not require drilling, and they communicate with the other security system components wirelessly.

Contact Motion Sensors (door/window)::- Most contact motion sensors are passive infrared sensors. They trigger an alarm if the protected door or window is opened while the system is armed.

Proximity

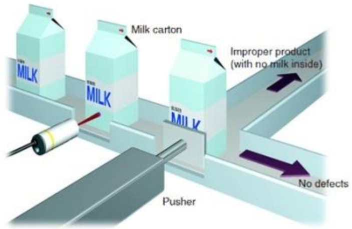
A proximity sensor is a sensor able to detect the presence of nearby objects without any physical contact.

A proximity sensor often emits an electromagnetic field or a beam of electromagnetic radiation (infrared , for instance), and looks for changes in the field or return signal. The object being sensed is often referred to as the proximity sensor's target.

Different proximity sensor targets demand different sensors.

For example, a capacitive or photoelectric sensor might be suitable for a plastic target; an inductive proximity sensor always requires a metal target. The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range or means to report a graduated detection distance. Some know this process as "thermo sensation". Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

Proximity sensors are commonly used on smart phones to detect (and skip) accidental touch screen taps when held to the ear during a call. They are also used in machine vibration monitoring to measure the variation in distance between a shaft and its support bearing. This is common in large steam turbines , compressors , and motors that use sleeve-type bearings.



Specifically, in the industrial sector, the wireless proximity sensors can be

Inductive: they detect metal objects;

Capacitive: they indicate the level and the fill amount present in containers, behind overings. They are used to track all objects including non-metallic ones;

Magnetic: they collect the data of interest in hostile environment (eg contaminated or affected by liquids) and when the inductive sensors are not effective;

Ultrasonic: they are widely used in automotive such as parking sensors and reverse;

Optical: they recognize, for non-contact and precisely, the positioning of the object.

Proximity Sensors

A Proximity Sensor is a non-contact type sensor that detects the presence of an object. Proximity Sensors can be implemented using different techniques like Optical (like Infrared or Laser), Ultrasonic, Hall Effect, Capacitive, etc.

Fig 33 proximity sensor

Some of the applications of Proximity Sensors are Mobile Phones, Cars (Parking Sensors), industries (object alignment), Ground Proximity in Aircrafts, etc.

Infrared Sensor (IR Sensor)

IR Sensors or Infrared Sensor are light based sensor that are used in various applications like Proximity and Object Detection. IR Sensors are used as proximity sensors in almost all mobile phones.

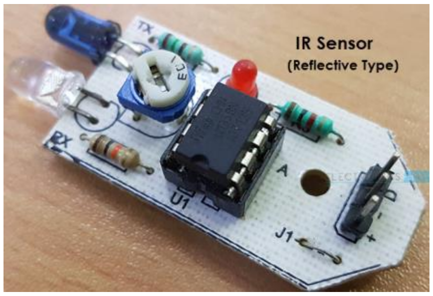


Fig 34 IR sensor

There are two types of Infrared or IR Sensors: Transmissive type and Reflective type. **In Transmissive Type IR Sensor**, the IR Transmitter (usually an IR LED) and the IR Detector (usually a Photo Diode) are positioned facing each other so that when an object passes between them, the sensor detects the object.

Reflective type IR Sensor. In this, the transmitter and the detector are positioned adjacent to each other facing the object. When an object comes in front of the sensor, the sensor detects the object.

Different applications where IR Sensor is implemented are Mobile Phones, Robots, Industrial assembly, automobiles etc.

A small project, where IR sensors are used to turn on street lights: street lights using IR sensors.

The following is a small list of projects based on few of the above mentioned sensors.

Light sensor – light detector using ldr

Smoke sensor – smoke detector alarm circuit

Alcohol sensor – how to make alcohol breathalyzer circuit?

Touch sensor – touch dimmer switch circuit using Arduino

Color sensor – Arduino based color detector

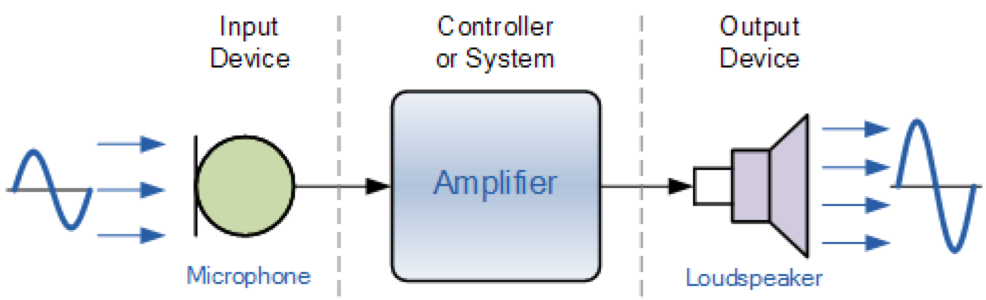
Humidity sensor – dht11 humidity sensor on Arduino

The word "Transducer" is the collective term used for both Sensors which can be used to sense a wide range of different energy forms such as movement, electrical signals, radiant energy, thermal or magnetic energy etc, and Actuators which can be used to switch voltages or currents.

There are many different types of sensors and transducers, both analogue and digital and input and output available to choose from. The type of input or output transducer being used, really depends upon the type of signal or process being "Sensed" or "Controlled" but we can define a sensor and transducers as devices that converts one physical quantity into another.

Electrical Transducers are used to convert energy of one kind into energy of another kind, so for example, a microphone (input device) converts sound waves into electrical signals for the amplifier to amplify (a process), and a loudspeaker (output device) converts these electrical signals back into sound waves and an example of this type of simple Input/Output (I/O) system is given below.

Simple Input/Output System using Sound Transducers



There are many different types of sensors and transducers available in the marketplace, and the choice of which one to use really depends upon the quantity being measured or controlled, with the more common types given in the table below

Common Sensors and Transducers

Quantity being Measured	Input Device (Sensor)	Output Device (Actuator)
Light Level	Light Dependant Resistor (LDR) Photodiode Photo-transistor Solar Cell	Lights & Lamps LED's & Displays Fibre Optics
Temperature	Thermocouple Thermistor Thermostat Resistive Temperature Detectors	Heater Fan
Force/Pressure	Strain Gauge Pressure Switch Load Cells	Lifts & Jacks Electromagnet Vibration
Position	Potentiometer Encoders Reflective/Slotted Opto-switch LVDT	Motor Solenoid Panel Meters
Speed	Tacho-generator Reflective/Slotted Opto-coupler Doppler Effect Sensors	AC and DC Motors Stepper Motor Brake
Sound	Carbon Microphone	Bell Buzzer

Piezo-electric Crystal Loudspeaker

Input type transducers or sensors, produce a voltage or signal output response which is proportional to the change in the quantity that they are measuring (the stimulus). The type or amount of the output signal depends upon the type of sensor being used. But generally, all types of sensors can be classed as two kinds, either Passive Sensors or Active Sensors.

Generally, active sensors require an external power supply to operate, called an excitation signal which is used by the sensor to produce the output signal. Active sensors are self-generating devices because their own properties change in response to an external effect producing for example, an output voltage of 1 to 10v DC or an output current such as 4 to 20mA DC. Active sensors can also produce signal amplification.

A good example of an active sensor is an LVDT sensor or a strain gauge. Strain gauges are pressure-sensitive resistive bridge networks that are external biased (excitation signal) in such a way as to produce an output voltage in proportion to the amount of force and/or strain being applied to the sensor.

Unlike an active sensor, a passive sensor does not need any additional power source or excitation voltage. Instead a passive sensor generates an output signal in response to some external stimulus. For example, a thermocouple which generates its own voltage output when exposed to heat. Then passive sensors are direct sensors which change their physical properties, such as resistance, capacitance or inductance etc.

But as well as analogue sensors, Digital Sensors produce a discrete output representing a binary number or digit such as a logic level “0” or a logic level “1”

Analogue and Digital Sensors

Analogue Sensors

Analogue Sensors produce a continuous output signal or voltage which is generally proportional to the quantity being measured. Physical quantities such as Temperature, Speed, Pressure, Displacement, Strain etc are all analogue quantities as they tend to be continuous in nature. For example, the temperature of a liquid can be measured using a thermometer or thermocouple which continuously responds to temperature changes as the liquid is heated up or cooled down.

Thermocouple used to produce an Analogue Signal

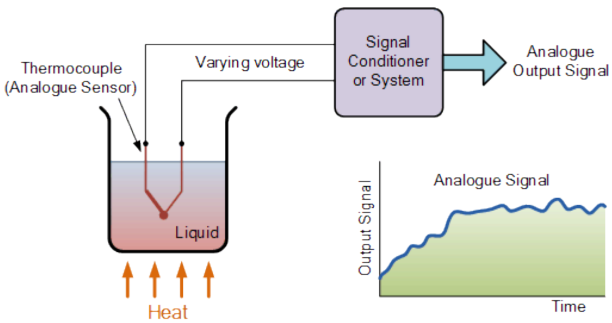


Fig34 thermocouple

Analogue sensors tend to produce output signals that are changing smoothly and continuously over time. These signals tend to be very small in value from a few mico-volts (uV) to several milli-volts (mV), so some form of amplification is required.

Then circuits which measure analogue signals usually have a slow response and/or low accuracy. Also analogue signals can be easily converted into digital type signals for use in micro-controller systems by the use of analogue-to-digital converters, or ADC's.

Digital Sensors

As its name implies, Digital Sensors produce a discrete digital output signals or voltages that are a digital representation of the quantity being measured. Digital sensors produce a Binary output signal in the form of a logic "1" or a logic "0", ("ON" or "OFF"). This means then that a digital signal only produces discrete (non-continuous) values which may be outputted as a single “bit”, (serial transmission) or by combining the bits to produce a single “byte” output (parallel transmission).

Light Sensor used to produce an Digital Signal

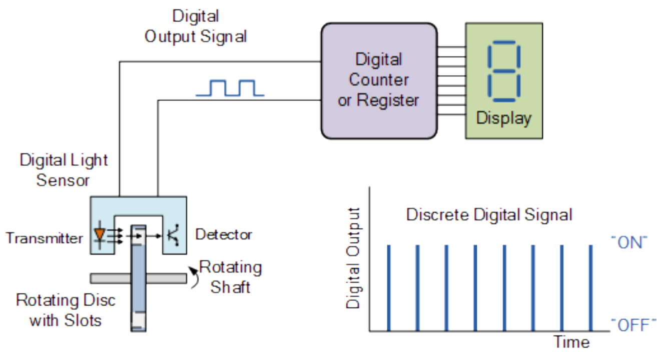


Fig 35 light sensor

In our simple example above, the speed of the rotating shaft is measured by using a digital LED/Opto-detector sensor. The disc which is fixed to a rotating shaft (for example, from a motor or robot wheels), has a number of transparent slots within its design. As the disc rotates with the speed of the shaft, each slot passes by the sensor in turn producing an output pulse representing a logic “1” or logic “0” level.

These pulses are sent to a register of counter and finally to an output display to show the speed or revolutions of the shaft. By increasing the number of slots or “windows” within the disc more output pulses can be produced for each revolution of the shaft. The advantage of this is that a greater resolution and accuracy is achieved as fractions of a revolution can be detected. Then this type of sensor arrangement could also be used for positional control with one of the discs slots representing a reference position.

Compared to analogue signals, digital signals or quantities have very high accuracies and can be both measured and “sampled” at a very high clock speed. The accuracy of the digital signal is proportional to the number of bits used to represent the measured quantity. For example, using a processor of 8 bits, will produce an accuracy of 0.390% (1 part in 256). While using a processor of 16 bits gives an accuracy of 0.0015%, (1 part in 65,536) or 260 times more accurate. This accuracy can be maintained as digital quantities are manipulated and processed very rapidly, millions of times faster than analogue signals.

In most cases, sensors and more specifically analogue sensors generally require an external power supply and some form of additional amplification or filtering of the signal in order to produce a suitable electrical signal which is capable of being measured or used. One very good way of achieving both amplification and filtering within a single circuit is to use Operational Amplifiers as seen before.

Signal Conditioning of Sensors

As we saw in the Operational Amplifier tutorial, op-amps can be used to provide amplification of signals when connected in either inverting or non-inverting configurations.

The very small analogue signal voltages produced by a sensor such as a few milli-volts or even pico-volts can be amplified many times over by a simple op-amp circuit to produce a much larger voltage signal of say 5v or 5mA that can then be used as an input signal to a microprocessor or analogue-to-digital based system.

Therefore, to provide any useful signal a sensors output signal has to be amplified with an amplifier that has a voltage gain up to 10,000 and a current gain up to 1,000,000 with the amplification of the signal being linear with the output signal being an exact reproduction of the input, just changed in amplitude.

Then amplification is part of signal conditioning. So when using analogue sensors, generally some form of amplification (Gain), impedance matching, isolation between the input and output or perhaps filtering (frequency selection) may be required before the signal can be used and this is conveniently performed by Operational Amplifiers.

Also, when measuring very small physical changes the output signal of a sensor can become “contaminated” with unwanted signals or voltages that prevent the actual signal required from being measured correctly. These unwanted signals are called "Noise". This Noise or Interference can be either greatly reduced or even eliminated by using signal conditioning or filtering techniques as we discussed in the Active Filter tutorial.

By using either a Low Pass, or a High Pass or even Band Pass filter the "bandwidth" of the noise can be reduced to leave just the output signal required. For example, many types of inputs from switches, keyboards or manual controls are not capable of changing state rapidly and so low-pass filter can be used. When the interference is at a particular frequency, for example mains frequency, narrow band reject or Notch filters can be used to produce frequency selective filters.

Typical Op-amp Filters

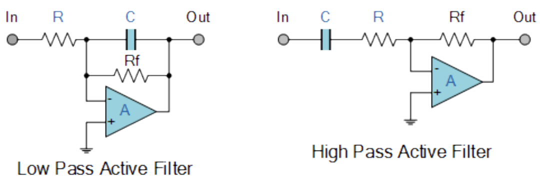


Fig 36 op Amp

Were some random noise still remains after filtering it may be necessary to take several samples and then average them to give the final value so increasing the signal-to-noise ratio. Either way, both amplification and filtering play an important role in interfacing both sensors and transducers to microprocessor and electronics based systems in "real world" conditions.

In the next tutorial about Sensors, we will look at Positional Sensors which measure the position and/or displacement of physical objects meaning the movement from one position to another for a specific distance or angle.

Temperature Sensors

Temperature Sensors measure the amount of heat energy or even coldness that is generated by an object or system, allowing us to "sense" or detect any physical change to that temperature producing either an analogue or digital output.

There are many different types of Temperature Sensor available and all have different characteristics depending upon their actual application. A temperature sensor consists of two basic physical types:

Contact Temperature Sensor :-Types These types of temperature sensor are required to be in physical contact with the object being sensed and use conduction to monitor changes in temperature. They can be used to detect solids, liquids or gases over a wide range of temperatures.

Non-contact Temperature Sensor Types: – These types of temperature sensor use convection and radiation to monitor changes in temperature. They can be used to detect liquids and gases that emit radiant energy as heat rises and cold settles to the bottom in convection currents or detect the radiant energy being transmitted from an object in the form of infra-red radiation (the sun).

The two basic types of contact or even non-contact temperature sensors can also be sub-divided into the following three groups of sensors, Electro-mechanical, Resistive and Electronic and all three types are discussed below.

The Thermostat

The Thermostat is a contact type electro-mechanical temperature sensor or switch, that basically consists of two different metals such as nickel, copper, tungsten or aluminium etc, that are bonded together to form a Bi-metallic strip. The different linear expansion rates of the two dissimilar metals produces a mechanical bending movement when the strip is subjected to heat.

The bi-metallic strip can be used itself as an electrical switch or as a mechanical way of operating an electrical switch in thermostatic controls and are used extensively to control hot water heating elements in boilers, furnaces, hot water storage tanks as well as in vehicle radiator cooling systems.

The Bi-metallic Thermostat

The thermostat consists of two thermally different metals stuck together back to back. When it is cold the contacts are closed and current passes through the thermostat. When it gets hot, one metal expands more than the other and the bonded bi-metallic strip bends up (or down) opening the contacts preventing the current from flowing.

On/Off Thermostat

There are two main types of bi-metallic strips based mainly upon their movement when subjected to temperature changes. There are the "snap-action" types that produce an instantaneous "ON/OFF" or "OFF/ON" type action on the electrical contacts at a set temperature point, and the slower "creep-action" types that gradually change their position as the temperature changes.

Snap-action type thermostats are commonly used in our homes for controlling the temperature set point of ovens, irons, immersion hot water tanks and they can also be found on walls to control the domestic heating system.

Creeper types generally consist of a bi-metallic coil or spiral that slowly unwinds or coils-up as the temperature changes. Generally, creeper type bi-metallic strips are more sensitive to temperature changes than the standard snap ON/OFF types as the strip is longer and thinner making them ideal for use in temperature gauges and dials etc.

Thermistor

The Thermistor is another type of temperature sensor, whose name is a combination of the words THERM-ally sensitive res-ISTOR. A thermistor is a special type of resistor which changes its physical resistance when exposed to changes in temperature.

Thermistors are generally made from ceramic materials such as oxides of nickel, manganese or cobalt coated in glass which makes them easily damaged. Their main advantage over snap-action types is their speed of response to any changes in temperature, accuracy and repeatability.

Most types of thermistor’s have a Negative Temperature Coefficient of resistance or (NTC), that is their resistance value goes DOWN with an increase in the temperature, and of course there are some which have a Positive Temperature Coefficient, (PTC), in that their resistance value goes UP with an increase in temperature.

Thermistors are constructed from a ceramic type semiconductor material using metal oxide technology such as manganese, cobalt and nickel, etc. The semiconductor material is generally formed into small pressed discs or balls which are hermetically sealed to give a relatively fast response to any changes in temperature.

Thermistors are rated by their resistive value at room temperature (usually at 25^{o}C), their time constant (the time to react to the temperature change) and their power rating with respect to the current flowing through them. Like resistors, thermistors are available with resistance values at room temperature from 10’s of MΩ down to just a few Ohms, but for sensing purposes those types with values in the kilo-ohms are generally used.

Thermistors are passive resistive devices which means we need to pass a current through it to produce a measurable voltage output. Then thermistors are generally connected in series with a suitable biasing resistor to form a potential divider network and the choice of resistor gives a voltage output at some pre-determined temperature point or value:

Fig 37 Typical Thermistor

An NTC thermistors reduces its resistance with an increase in temperature and are available in a variety of base resistances and temperature curves. NTC thermistors are usually characterised by their base resistance at room temperature, that is 25^oC, (77^oF) as this provides a convenient reference point. So for example, 2k2Ω at 25^oC, 10kΩ at 25^oC or 47kΩ at 25^oC, etc.

Another important characteristic of a thermistor is its "B" value. The B value is a material constant which is determined by the ceramic material from which it is made. it describes the gradient of the resistive (R/T) curve over a particular temperature range between two temperature points. Each thermistor material will have a different material constant and therefore a different resistance versus temperature curve.

Then the B value will define the thermistors resistive value at a first temperature or base point, (which is usually 25^oC), called T1, and the thermistors resistive value at a second temperature point, for example 100^oC, called T2. Therefore the B value will define the thermistors material constant between the range of T1 and T2. That is $B_{T1/T2}$ or $B_{25/100}$ with typical NTC thermistor B values given anywhere between about 3000 and about 5000.

Note however, that both the temperature points of T1 and T2 are calculated in the temperature units of Kelvin where 0^0C = 273.15 Kelvin. Thus a value of 25^oC is equal to 25^o + 273.15 = 298.15K, and 100^oC is equal to 100^o + 273.15 = 373.15K, etc.

So by knowing the B value of a particular thermistor (obtained from manufacturers datasheet), it is possible to produce a table of temperature versus resistance to construct a suitable graph using the following normalised equation:

Thermistor Equation

$$B_{(T1/T2)} = \frac{T_2 \times T_1}{T_2 - T_1} \times \ln\left(\frac{R_1}{R_2}\right)$$

- Where:
- T1 is the first temperature point in Kelvin
- T2 is the second temperature point in Kelvin
- R1 is the thermistors resistance at temperature T1 in Ohms
- R2 is the thermistors resistance at temperature T2 in Ohms

Thermistor Example No1

A 10kΩ NTC thermistor has a B value of 3455 between the temperature range of 25°C and 100°C. Calculate its resistive value at 25°C and again at 100°C.

Data given: B = 3455, R1 = 10kΩ at 25°. In order to convert the temperature scale from degrees Celsius, °C to degrees Kelvin add the mathematical constant 273.15

The value of R1 is already given as 10kΩ base resistance, thus the value of R2 at 100°C is calculated as:

$$B_{(25/100)} = \frac{(100+273.15)\times(25+273.15)}{(100+273.15)-(25+273.15)} \times \ln\left(\frac{10000}{R_X}\right)$$

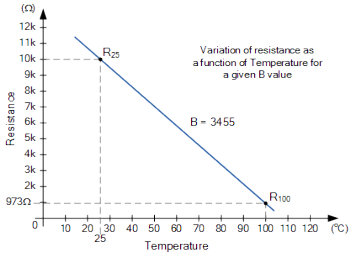
$$3455 = \frac{111254.6725}{75} \times \ln\left(\frac{10000}{R_X}\right)$$

$$3455 = 1483.4 \times \ln\left(\frac{10000}{R_X}\right)$$

$$e^{\left[\frac{3455}{1483.4}\right]} = \frac{10000}{R_X}$$

$$\therefore R_X = \frac{10000}{e^{2.33}} = 973\Omega$$

Giving the following two point characteristics graph of:

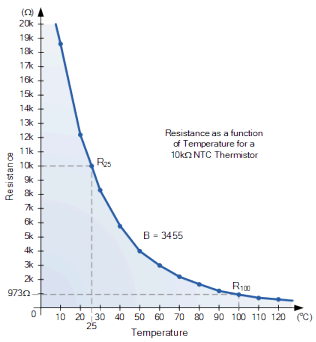


Note that in this simple example, only two points were found, but generally thermistors change their resistance exponentially with changes in temperature so their characteristic curve is nonlinear, therefore the more temperature points are calculated the more accurate will be the curve.

Temperature (°C)	10	20	**25**	30	40	50	60	70	80	90	100	110	120
Resistance (Ω)	18476	12185	**10000**	8260	5740	4080	2960	2188	1645	1257	973	765	608

and these points can be plotted as shown to give a more accurate characteristics curve for the 10kΩ NTC Thermistor which has a B-value of 3455.

NTC Thermistor Characteristics Curve



Notice that it has a negative temperature coefficient (NTC), that is its resistance decreases with increasing temperatures.

Resistive Temperature Detectors (RTD).

Another type of electrical resistance temperature sensor is the Resistance Temperature Detector or RTD. RTD's are precision temperature sensors made from high-purity conducting metals such as platinum, copper or nickel wound into a coil and whose electrical resistance changes as a function of temperature, similar to that of the thermistor. Also available are thin-film RTD's. These devices have a thin film of platinum paste is deposited onto a white ceramic substrate.

Resistive temperature detectors have positive temperature coefficients (PTC) but unlike the thermistor their output is extremely linear producing very accurate measurements of temperature.

However, they have very poor thermal sensitivity, that is a change in temperature only produces a very small output change for example, $1\Omega/^oC$.

The more common types of RTD's are made from platinum and are called **Platinum Resistance Thermometer** or **PRT**'s with the most commonly available of them all the Pt100 sensor, which has a standard resistance value of 100Ω at 0^oC. The downside is that Platinum is expensive and one of the main disadvantages of this type of device is its cost.

Like the thermistor, RTD's are passive resistive devices and by passing a constant current through the temperature sensor it is possible to obtain an output voltage that increases linearly with temperature. A typical RTD has a base resistance of about 100Ω at 0^oC, increasing to about 140Ω at 100^oC with an operating temperature range of between -200 to $+600^oC$. Because the RTD is a resistive device, we need to pass a current through them and monitor the resulting voltage. However, any variation in resistance due to self heat of the resistive wires as the current flows through it, I^2R , (Ohms Law) causes an error in the readings. To avoid this, the RTD is usually connected into a Wheatstone Bridge network which has additional connecting wires for lead-compensation and/or connection to a constant current source.

The Thermocouple

The Thermocouple is by far the most commonly used type of all the temperature sensor types. Thermocouples are popular due to its simplicity, ease of use and their speed of response to changes in temperature, due mainly to their small size. Thermocouples also have the widest temperature range of all the temperature sensors from below -200^{o}C to well over 2000^{o}C.

Thermocouples are thermo electric sensors that basically consists of two junctions of dissimilar metals, such as copper and constantan that are welded or crimped together. One junction is kept at a constant temperature called the reference (Cold) junction, while the other the measuring (Hot) junction. When the two junctions are at different temperatures, a voltage is developed across the junction which is used to measure the temperature sensor as shown below.

Thermocouple Colour Codes

Thermocouple Sensor Colour CodesExtension and Compensating Leads

Code Type	Conductors (+/-)	Sensitivity	British BS 1843:1952
E	Nickel Chromium / Constantan	-200 to 900^{o}C	
J	Iron / Constantan	0 to 750^{o}C	
K	Nickel Chromium / Nickel Aluminium	-200 to 1250^{o}C	
N	Nicrosil / Nisil	0 to 1250^{o}C	
T	Copper / Constantan	-200 to 350^{o}C	
U	Copper / Copper Nickel Compensating for "S" and "R"	0 to 1450^{o}C	

The three most common thermocouple materials used above for general temperature measurement are Iron-Constantan (Type J), Copper-Constantan (Type T), and Nickel-Chromium (Type K). The output voltage from a thermocouple is very small, only a few millivolts (mV) for a 10^{o}C change in temperature difference and because of this small voltage output some form of amplification is generally required.

Linear Variable Differential Transformer

linear variable differential transformer that the LVDT is a positional sensor used to measure small linear (straight-line) displacements from a few millimters to many hundreds of millimeters. The LVDT has no direct sliding mechanical contact or moving parts to wear out, thus making it virtually friction free, offering a greater electrical performance and life-span compared to the resistive linear potentiometer type displacement sensor.

The LVDT consists of a transformer with a single primary winding and two secondary windings which are electrically out-of-phase from each other by 180^{o}. The LVDT also consists of a movable core. When the core is at its central position, the voltages induced in the two secondary windings are equal and opposite giving zero output signal. As the core moves away from its center position, the induced voltage in one half secondary winding will be greater than the other, giving a signal whose amplitude is proportional to the amount of linear displacement and whose phase represents the direction of travel. Thus the LVDT produces a differential voltage output that varies linearly with the cores position with the phase angle of the output voltage changing by 180^{o} as the core is moved from one side of the null position to the other.

If the measured displacement of the internal core of an LVDT is changed from a linear movement to rotary or angular movement, then the device becomes a rotary variable differential transformer (RVDT). However, the output signal of an RVDT is truely linear over a relatively small range of angular rotation and is not suitable for measuring a full 360^{o} of rotation.

The Linear Variable Differential Transformer is a very accurate and frictionless positional transducer used for measuring the linear displacement of an object with an output voltage proportional to the position of its moveable core

A Linear Variable Differential Transformer, or LVDT for short, is an electromechanical position transducer (sensor) which provides accurate and frictionless positional feedback information about the linear mechanical position of an external force or object. As its name suggests, the linear variable differential transformer works on the same principle as the AC transformer but instead of supplying a load current or high voltage, it uses basic transformer principles of mutual inductance to measure linear movement.

Fig Typical Linear Variable Differential Transformer Sensor

LVDT Example No1

A linear variable differential transformer has a stroke length of ±150mm and produces a resolution of 40mV/mm. Determine: a) the LVDT's maximum output voltage, b) the output voltage when the core is moved 120mm from its null position, c) the core position from center when the output voltage is 3.75 volts, d) the change in output voltage when the core is moved from +80mm to -80mm displacement.

a). The maximum output voltage, V_{OUT}

If 1mm of movement produces 40mV, then 150mm of movement produces:

V_{OUT} = 40mV x 150mm = 0.04 x 150 = ±6 Volts

b). V_{OUT} with 120mm of core displacement

If a core displacement of 150mm produces an output of 6 volts, then a movement of 120mm produces:

$$V_{OUT} = \frac{\text{Core Displacement} \times V_{MAX}}{\text{Length}}$$

$$V_{OUT} = \frac{120\,\text{mm} \times 6\,\text{V}}{150\,\text{mm}} = \frac{120 \times 6}{150} = 4.8\,\text{Volts}$$

c). Core position when V_{OUT} = 3.75 volts

$$V_{OUT} = \frac{\text{Core Displacement} \times V_{MAX}}{\text{Length}}$$

$$\therefore \text{ Displacement} = \frac{V_{OUT} \times \text{Length}}{V_{MAX}}$$

$$D = \frac{3.75\,\text{V} \times 150\text{mm}}{6\,\text{V}} = \frac{3.75 \times 150}{6} = 93.75\,\text{mm}$$

d). Voltage change from +80mm to -80mm displacement

$$V_{CHANGE} = \frac{+80\,\text{mm} - (-80\,\text{mm}) \times 6\,\text{V}}{150\,\text{mm}} = \frac{80 - (-80) \times 6}{150} = 6.4\,\text{Volts}$$

Thus the output voltage changes from +3.2 volts to -3.2 volts as the core moves from +80mm to -80mm respectively.

Displacement transducers come in many lengths and sizes for measuring a few millimeters to ones that can measure long strokes. But while LVDT's are able to measure linear movement in a straight line, there is a variation of the LVDT which can measure angular movement called the Rotary Variable Differential Transformer or RVDT.

Flow sensors.

Flow sensors are devices which are used to measure a flow rate of Fluid. These sensors are generally part of a flow meter that would help to measure the flow rate. Nowadays many different types of flow sensors are available which are used for different purpose.

Most important types of flow sensors which are widely used

Oval Gear Flow Meter: It is a positive displacement flow meter with two oval shape gear; it measures flow when it passes through a chamber and magnetic pick-up sensor use for measuring rotation quantity of gear.

Turbine Flow Sensor: It is a flow meter which uses the mechanical energy to rotate the rotor in the direction of the flow and it measures the velocity of the liquid. Rotor shaft moves fast proportionally with the increasing water speed. The sensing system is available to measure the flow in both forward and backward direction.

. **RTD Sensor:** Here, RTD stands for Resistance Temperature Detector sensor and it is used to measure temperature. RTD consist of the wire made from pure metal like Platinum, copper or nickel.

Water Flow Sensor: It is used to measure the water flow in pulse rate output and it usually consists of injection molding machine and other molds and tools.

Pressure meter

Types of pressure measurements

Pressure sensors can be classified in terms of pressure ranges they measure, temperature ranges of operation, and most importantly the type of pressure they sensors are variously named according to their purpose, but the same technology may be used under different names.

Absolute pressure sensor:-This sensor measures the pressure relative to perfect vacuum.

Gauge pressure sensor:- This sensor measures the pressure relative to atmospheric pressure. A tire pressure gauge is an example of gauge pressure measurement; when it indicates zero, then the pressure it is measuring is the same as the ambient pressure.

Vacuum pressure sensor:- This term can cause confusion. It may be used to describe a sensor that measures pressures below atmospheric pressure, showing the difference between that low pressure and atmospheric pressure (i.e. negative gauge pressure),but it may also be used to describe a sensor that measures low pressure relative to perfect vacuum (i.e. absolute pressure).

Differential pressure sensor:- This sensor measures the difference between two pressures, one connected to each side of the sensor. Differential pressure sensors are used to measure many properties, such as pressure drops across oil filters or air filters, fluid levels (by comparing the pressure above and below the liquid) or flow rates (by measuring the change in pressure across are striction). Technically speaking, most pressure sensors are really differential pressure sensors; for example a gauge pressure sensor is merely a differential pressure sensor in which one side is open to the ambient atmosphere.

Sealed pressure sensor:- This sensor is similar to a gauge pressure sensor except that it measures pressure relative to some fixed pressure ather than the ambient atmospheric pressure (which varies according to the location and the weather).

Pressure-sensing technology:- There are two basic categories of analog pressure sensors, Force collector types These types of electronic pressure sensors generally use a force collector (such a diaphragm, piston, bourdon tube, or bellows) to measure strain (or deflection) due to applied force over an area (pressure).

Piezo resistive strain gauge Uses the piezo resistive effect of bonded or formed strain gauges to detect strain due to applied pressure, resistance increasing as pressure deforms the material. Common technology types are Silicon (Monocrystalline), Polysilicon Thin Film, Bonded Metal Foil, Thick Film, and Sputtered Thin Film. Generally, the strain gauges are connected to form a Wheatstone bridge circuit to maximize the output of the sensor and to reduce sensitivity to errors. This is the most commonly employed sensing technology for general purpose pressure measurement.

Capacitive Uses a diaphragm and pressure cavity to create a variable capacitor to detect strain due to applied pressure, capacitance decreasing as pressure deforms the diaphragm. Common technologies use metal, ceramic, and silicon diaphragms.

Electromagnetic Measures the displacement of a diaphragm by means of changes in inductance (reluctance), LVDT, Hall Effect, or by eddy current principle.

Piezoelectric Uses the piezoelectric effect in certain materials such as quartz to measure the strain upon the sensing mechanism ue to pressure. This technology is commonly employed for the measurement of highly dynamic pressures.

Optical Techniques include the use of the physical change of an optical fiber to detect strain due to applied pressure.

A common example of this type utilizes Fiber Bragg Gratings. This technology is employed in challenging applications where the measurement may be highly remote, under high temperature, or may benefit from technologies inherently mmune to electromagnetic interference. Another analogous technique utilizes an elastic film constructed in layers that can change reflected wavelengths according to the applied pressure (strain).

Potentiometric Uses the motion of a wiper along a resistive mechanism to detect the strain caused by applied pressure.

Resonant Uses the changes in resonant frequency in a sensing mechanism to measure stress, or changes in gas density, caused by applied pressure. This technology may be used in conjunction with a force collector, such as those in the category above. Alternatively, resonant technology may be employed by exposing the resonating element itself to the media, whereby the resonant frequency is dependent upon the density of the media. Sensors have been made out of vibrating wire, vibrating cylinders, quartz, and silicon MEMS. Generally, this technology is considered to provide verystable readings over time.

Thermal Uses the changes in thermal conductivity of a gas due to density changes to measure pressure. A common example of this type is the Pirani gauge.

Ionization Measures the flow of charged gas particles (ions) which varies due to density changes to measure pressure. Common examples are the Hot and Cold Cathode gauges.

There are many applications for pressure sensors:

Pressure sensing This is where the measurement of interest is pressure, expressed as a force per unit area. This is useful in weather instrumentation, aircraft, automobiles, and any other machinery that has pressure functionality implemented.

Altitude sensing This is useful in aircraft, rockets, satellites, weather balloons, and many other applications. All these applications make use of the relationship between changes in pressure relative to the altitude. This relationship is governed by the following equation:

This equation is calibrated for an altimeter, up to 36,090 feet (11,000 m). Outside that range, an error will be introduced which can be calculated differently for each different pressure sensor. These error calculations will factor in the error introduced by the change in temperature as we go up.

Barometric pressure sensors can have an altitude resolution of less than 1 meter, which is significantly better than GPS systems (about 20 meters altitude resolution). In navigation applications altimeters are used to distinguish between stacked road levels for car navigation and floor levels in buildings for pedestrian navigation..

Thermometers

There are a wide variety of thermometers available on the market today. Some highly precise measurements are still done with glass thermometers. Since the properties of fluids, and in particular, mercury are well known, the only limitation to accuracy and resolution come in the form of how well you can manufacture a glass tube with a precision bore. Some manufacturers have made thermometers that have variable scales for specific uses. One such use is a process called wet viscosity. In this process it is important to know the precise temperature of the water bath. The glass thermometer is still used because of it extreme repeatability. These specialized thermometers have a bore that narrows at a particular point. In this way it can expand a two degree temperature range in the middle of its scale to approximately two inches long, allowing readings down to a fraction of a tenth of a degree C.

Many of today's thermometers use fluids other than mercury due to the hazards of spilled mercury. These newer devices use other fluids that have been engineered to have specific rates of expansion.

The draw back to these fluids is that they typically do not have the high temperature capabilities that mercury does. One major drawback of the glass thermometer is the limited pressure capacity of the glass. Also inserting the glass bulb into a pressurized fluid or chamber caused the accuracy of the thermometer to suffer. This ledto the use of A thermowell is a closed end metal tube that sticks into the chamber or fluid, and the thermometer sits in this well, making contact with its sides

A valve is a device for controlling the passage of fluid/Pressure/Level through a Pipe or duct/Tank, especially an automatic device allowing movement in one direction. Two type of

valve's are used in industries,

1.Control Valve

2.On/Off Valve.

Control instrumentation plays a significant role in both gathering information from the field and changing the field parameters, and as such are a key part of control loops.

Buzzers

A buzzer is a mechanical, electromechanical, magnetic, electromagnetic, electro-acoustic or piezoelectric audio signalling device. A piezo electric buzzer can be driven by an oscillating electronic circuit or other audio signal source. A click, beep or ring can indicate that a button has been pressed.

Types of Buzzers

There are several different kinds of buzzers. At Future Electronics we stock many of the most common types categorized by Type, Sound Level, Frequency, Rated Voltage,

Dimension and packaging Type. The parametric filters on our website can help refine your search results depending on the required specifications.

The most common sizes for Sound Level are 80 dB, 85 dB, 90 dB and 95 dB. We also carry buzzers with Sound Level up to 105 dB. There are several types available including Electro- Acoustic, Electromagnetic, Electromechanic, Magnetic and Piezo, among others.

Magnetic contactors

A contactor is an electrically controlled switch used for switching an electrical power circuit, similar to a relay except with higher current ratings and a few other differences A contactor is controlled by a circuit which has a much lower power level than the switched circuit.

Magnetic contactor is common used in automation industry for motor control application. It is function basically like “relay”. The power source into the coil of winding, it like the solenoid operation. It can delivery a big ampere to the loads and very long lasting and high durability.

When the power is “on”,it energized the coil and make plunger move and the switch contact is change from normally open to closed position. It allowed the current move from input terminal to output terminal. Then if we connected to the 3 phase motor,it will running :D

What is magnetic contactor?

This device have a several component :

1) **Main contact**

– This contact used for switching the power supply to device to On or Off position.

2) **Axillary contact**

– This contact used for control circuit purpose. It have two contact :- NO (Normally Open) & NC (Normally Close)

3) Power supply (Coil)

– This is for energized the solenoid. It have in several range of power supply (24 VDC,24 VAC,110 VAC,240 VAC,415 VAC)

4) Auxillary Block

-This is for additional for Auxiliary contact (NO or NC)

Typical applications for magnetic contactor:

- Electronic switching
- Lighting
- Resistive loads
- Non-motor-related inductive loads

Disconnect switches

VFD bypass/isolation

1. **Types**:

(i) Electromagnetic

(ii) Electro-pneumatic

(iii) Pneumatic

Important Terms and Definitions related to Motor Control and Protection

2. **Interrupting Medium**:

(**i**) Air

(**ii**) Oil

(**iii**) SF6 gas

(**iv**) Vacuum

Abnormal Operating Condition and Causes of Induction Motors

3. Rated values of voltages:

(**i**) **Rated voltage** (Operational voltage)

For a three phase contactors, the voltage between phases is called rated voltage or operational voltage.

(**ii**) **Rated Insulation Voltage** The voltage, on which performs the dielectric test.

The Star-Delta (Y-Δ) 3-phase Motor Starting Method by Automatic star-delta starter with Timer.

4. Rated Values of Current:

(**i**) **Rated Thermal Current** the maximum current, on which a Contactor operates continuously for eight (8) hours without increasing the temperature (increased with a permissible limit).

(ii) Rated Operational Current a Manufacturer tells the rated operational current considering Contactor's rated frequency, operational voltages, rated duty and utilization factor.

Main Difference between contactor and Starter.

5. Rated duty and Serves Conditions:

(**i**) **Eight Hours Duty** A Contactor can carry the normal current for more than 8 hours. The contactor's rated thermal current can be found by 8 hours duty.

(**ii**) **Uninterrupted duty** A Contactor can be close for a long time (from 8 hours to many years) without interruption. However, Due to Oxidation and dust on contacts,

Temperature may be increased.

(**iii**) **Contactor's making Capacity** Contactor's rated making capacity is the value of current, on which the contacts of contactor can make the connections (i.e. Contactor can close their contacts) without arcing or melting. A.C contactor's making capacity is defined according to the Current Symmetrical Component's R.M.S value.

(**iv**) **Contactor's Breaking Capacity** Contactor's rated breaking capacity is the value of current, on which the contacts of contactor can break the connections (i.e. Contactor can open their contacts) without arcing or melting. A.C contactor's breaking capacity is defined according to the Current R.M.S value.

Photo-sensors

A photoelectric sensor is an instrument designed to detect the distance, absence, or presence of an object by using a light transmitter such as an infrared, and a photoelectric receiver. They are also referred to as photo eyes.

Photoelectric sensors contain the following components: Emitter - A light source such as an LED or laser diode

Photodiode/phototransistor receiver - To detect the light source **Supporting electronics** - For amplifying the signal relayed from the receiver.

Types of Photoelectric Sensors

The types of photoelectric sensors commonly found are mentione below:

Laser photoelectric sensors - Lasers are sometimes used as sensor light sources. Laser photoelectric sensors are available in thru-beam, diffuse scan, and diffuse scan with background suppression versions. Lasers provide high intensity visible light, which enables simple assembly and adjustment. Laser technology makes it possible to detect extremely small objects at a distance.

Fiber optics photoelectric sensors – These sensors use an emitter, receiver, and a flexible cable that is full of tiny fibers meant to transmit light. When glass fibers are used, the emitter source is infrared light. When plastic fibers are used, the emitter source is visible light. Fiber optics can be adapted to thru-beam, retro-reflective scan, or diffuse scan sensors. Fiber optics works best for small sensing areas or small objects.

Remote photoelectric sensors – These are used for remote sensing and contain only the optical components of a sensor

Application vs. Technology Comparison			
Application	**Not Recommended**	**Good**	**Best**
Detecting transparent or translucent objects at short ranges (25 mm or less)	Ultrasonic	Photoelectric	Capacitive
Sensing transparent or translucent objects at long ranges (> 25 mm)	Capacitive	Photoelectric	Ultrasonic
Detecting objects or substance levels through non-metallic container walls	Ultrasonic	Photoelectric	Capacitive
Detecting liquid or granular material level in an open container (>25-mm sensing range required)	Capacitive	Photoelectric	Ultrasonic
Sensing small targets at long ranges	Capacitive	Ultrasonic	Photoelectric
Detecting targets at long ranges in dusty, dirty environments	Capacitive	Photoelectric	Ultrasonic
Sensing target shape details	Ultrasonic	Capacitive	Photoelectric
Detecting targets close to backgrounds	Ultrasonic	Capacitive	Photoelectric

Self check - 5	Written test

Directions: **Matching questions**

A	B .
……1 Input device	A. Motor
…….2. Output device	B. Pushbuttons
…….3. PLC	C. The brain of the computer/PLC
…….4. CPU	D. microcomputer

Note: Satisfactory rating –5 and above points Unsatisfactory - below 5points

Answer Sheet

Score = ____________

Rating: _____________

Name :___________________________Date:________________

LG #27	LO #2- Install/Test field and control devices

Instruction sheet

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

- Wearing appropriate personal protective equipment
- Following Occupational Health and Safety policies and procedures
- Installing and testing devices
- Preparing report on installation and testing of equipment
- Responding to unplanned Events/conditions

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:

- Wear appropriate personal protective equipment
- Follow Occupational Health and Safety policies and procedures
- Install and test devices
- Prepare report on installation and testing of equipment
- Respond to unplanned Events/conditions

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 Wearing appropriate personal protective equipment

1.1 Wearing appropriate personal protective equipment

Personal protective equipment (PPE)

PPE is equipment that will protect the trainees against health or safety risks at work. It can include items such as safety helmets, gloves, eye protection, high-visibility clothing, safety footwear and safety harnesses. It also includes respiratory protective equipment (RPE).

Importance of PPE

Making the workplace safe includes providing instructions, procedures, training and supervision to encourage people to work safely and responsibly.

Even where engineering controls and safe systems of work have been applied, some hazards might remain. These include injuries to:

- the lungs, eg from breathing in contaminated air
- the head and feet, eg from falling materials
- the eyes, eg from flying particles or splashes of corrosive liquids
- the skin, eg from contact with corrosive materials
- the body, eg from extremes of heat or cold

PPE is needed in these cases to reduce the risk.

What do the trainee have to do?

- Only use PPE as a last resort

- If PPE is still needed after implementing other controls (and there will be circumstances when it is, eg head protection on most construction sites), you must provide this for your employees free of charge
- You must choose the equipment carefully (see selection details below) and ensure employees are trained to use it properly, and know how to detect and report any faults Selection and use

You should ask yourself the following questions:

- Who is exposed and to what?
- How long are they exposed for?
- How much are they exposed to?

When selecting and using PPE:

- Choose products which are CE marked in accordance with the Personal Protective Equipment (Enforcement) Regulations 2018 – suppliers can advise you
- Choose equipment that suits the user – consider the size, fit and weight of the PPE. If the users help choose it, they will be more likely to use it
- If more than one item of PPE is worn at the same time, make sure they can be used together, eg wearing safety glasses may disturb the seal of a respirator, causing air leaks
- Instruct and train people how to use it, eg train people to remove gloves without contaminating their skin. Tell them why it is needed, when to use it and what its limitations are

Table 1: Personal protective clothing and equipment

Safety equipment	Uses	Images
Head protection (hard hat)	Hard hat is used to protect head of the worker from any falling objects dropping from high level during construction.	
Over all cloths	Protects the normal clothes from dust, grease and other spilling materials.	
Safety shoe (boot)	Protects the worker form nail, sharp objects and heavy falling objects by hard-rolled leather shoes with metal toe caps	
Rubber boot	Protects the workers feet from colds, chemical, and mud in the working area.	
Mask	Protects eyes of the worker from other endangering object and dust during construction.	
Goggle	Protects eyes of the workers during welding of metal works and when placing reinforcement in the form work.	
Glove	Protects the workers from oils, chemicals, and dust and other dangerous material that affect the skin.	
Hand Guard	Protect hands of the worker while chiseling and hammering. It is available in different standard sizes of the chisel handle and designed for slipping over chisel handles	

Safety Belt	Secures laborers working in a plane where the construction is done at high level.	
Hearing protection	The noise levels in some areas on construction sites are often above the level which causes sensory hearing loss to workers in the vicinity.	

Self-Check 2	Written Test

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

Directions: For the following questions, say TRUE if the statement is correct and FALSE if it is incorrect (wrong).

1. Preventing accidents is crucial in a crowded workshop.
2. PPE is equipment that will protect the user against health or safety risks at work.
3. Earplugs are used to protect our eyes at work.
4. Gloves are used to protect our head at work.
5. PPE is needed in these cases to reduce the risk.

. Answer the following question!

Note: Satisfactory rating 6and 10points 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 2 Following Occupational Health and Safety policies and procedures

2.1 Following Occupational Health and Safety policies and procedures

Following Occupational Health and Safety policies and procedures

OSH and state safety laws have helped to provide safe working areas for electricians. Individuals can work safely on electrical equipment with today's safeguards and recommended work practices. In addition, an understanding of the principles of electricity is gained. Ask supervisors when in doubt about a procedure. Report any unsafe conditions, equipment, or work practices as soon as possible.

OHS includes the laws, standards, and programs that are aimed at making the workplace better for workers, along with co-workers, family members, customers, and other stakeholders. Who’s responsible for developing policies and procedures?

Administrative controls and protective clothing and equipment may provide interim solutions in a planned program to eliminate or reduce a particular risk, or they may be used in addition to other control methods. Specific health and safety policies and procedures should provide clear direction or instruction by which workplace hazards will be identified, and the risks assessed and controlled by the measures Described here.

A formal policy or procedure can ensure hazards are dealt with in a structured and agreed manner, rather than in response to a crisis. More information about hazard identification, risk assessment and risk control is with Workplace Health and Safety series.

Developing policies and procedures is a management responsibility. Consultation with employees however, is very important.

Consultation helps to create policies that can be understood, will work, and will be followed. Developing procedures does not make employees responsible for hazards at work. The responsibility for ensuring the workplace is safe and that work procedures are followed remains a responsibility of the employer.

There may be times when you need to call on specialist assistance from within or outside your organization to help develop policies and procedures.

Safety Procedures in a Workplace

Having the knowledge, skills and attitudes to carry out tasks safely is critical in any workplace. What skills will you need? Working safely is like driving safely.

In order to work safely you need to know about:

- OHS roles in the workplace
- OHS training and inductions
- Where to find OHS information
- Relevant signs
- Rules and procedures
- keeping up-to-date
- Reporting problems, accidents and incidents.

Follow the signs

Workplaces are signed to draw attention to hazards or requirements of different areas. Different types of signs in the workplace will be different colors and mean different things.

Mandatory signs

Mandatory signs are blue and white. They tell you things that you must do in a work area. They are often used to tell people to wear safety equipment or stick to the walkways.

Caution signs

Caution signs are yellow and black. They indicate workplace hazards such as forklifts, noise, radiation areas or overhead cranes.

Danger signs

Danger signs are always red, black and white. They indicate where no-go areas exist, such as high voltage areas or chemical storage areas

Self-Check 2	Written Test

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

Directions: For the following questions, say TRUE if the statement

is correct and FALSE if it is incorrect (wrong).

1. Developing policies and procedures is a management responsibility.
2. Different types of signs in the workplace will be different colors.
3. Mandatory signs are blue and white.
4. In order to work safely you need to know about relevant signs
5. OSH and state safety laws have helped to provide safe working areas for electricians.

. Answer the following question!

Note: Satisfactory rating 6 and 10 points Unsatisfactory below6 and 10 points

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

Answer Sheet

Score = ___________

Rating: ____________

Name: ___________________________ Date_______________

Information Sheet 3. Installing and testing devices

3. `1 Installing and testing devices

Most software systems have installation procedures that are needed before they can be used for their main purpose. Testing these procedures to achieve an installed software system that may be used is known as installation testing. These procedure may involve full or partial upgrades, and install/uninstall processes.

Installation testing may look for errors that occur in the installation process that affect the user's perception and capability to use the installed software. There are many events that may affect the software installation and installation testing may test for proper installation whilst checking for a number of associated activities and events. Some examples include the following:

- A user must select a variety of options.
- Dependent files and libraries must be allocated, loaded or located.
- Valid hardware configurations must be present.
- Software systems may need connectivity to connect to other software systems.

Installation testing may also be considered as an activity-based approach to how to test something. For example, install the software in the various ways and on the various types of systems that it can be installed. Check which files are added or changed on disk. Does the installed software work? What happens when you uninstall?

This testing is typically performed in Operational acceptance testing, by a software testing engineer in conjunction with the configuration manager. Implementation testing is usually defined as testing which places a compiled version of code into the testing or pre-production environment, from which it may or may not progress into production. unclear reference to implement testing This generally takes place outside of the software development environment to limit code corruption from other future or past releases (or from the use of the wrong version of dependencies such as shared libraries) which may reside on the development environment.

The simplest installation approach is to run an install program, sometimes called package software. This package software typically uses a setup program which acts as a multi-configuration wrapper and which may allow the software to be installed on a variety of machine and/or operating environments. Every possible configuration should receive an appropriate level of testing so that it can be released to customers with confidence.

Self-Check 3	Written Test

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

I. Answer the following question as directed below

1. ____________is testing procedures to achieve an installed software system

2.___________is considered as an activity-based approach to how to test

. Answer the following question!

Note: Satisfactory rating 1 and 2 points Unsatisfactory below 1 and 2 points

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

Score = ___________

Rating: ___________

Answer Sheet

Name: ____________________________ Date: _______________

Information Sheet 4. Preparing report on installation and testing of equipment

Preparing report on installation and testing of equipment

HOW TO PREPARE FOR EQUIPMENT INSTALLATION: CHECK LIST

Getting ready to have new equipment installed in your plant? Installing new equipment, whether in a brand-new production line or an existing line, can be challenging. To make the process as easy as possible and to save yourself time and money by decreasing the potential for downtime, ask the following questions before any new equipment installation.

1. First, be sure to talk to your supplier's project manager before starting preparation for the installation. He may have information that will affect your preparation. He also will be your main contact for questions regarding delivery of the project, and will give you an idea of what you need to have on hand and what you need to accomplish before equipment is delivered.

2. Ask your supplier about electrical requirements and other necessities that need to be on-site for proper installation. By asking this beforehand, you'll know exactly what you need to accomplish before the new equipment arrives. Here are some of the items you need to ask about:

a. Power (460V/3Ph/60hz, 120V, 24V or other)
b. Pneumatic (compressed air); 90 psi, 60 SCFM …
c. Dedusting (port diameter, multi points, pressure, flow rate …)
d. Communication cables (Ethernet or other)

3. Where are drop sites for these items located? Knowing this can help you save time and will help the supplier position the new equipment. Ask the project manager for the final layout and add drop sites if needed.

4. Are there out-of-the-ordinary environmental conditions at the plant? Installation can be difficult for service technicians when they have to work in such settings.

5. If installation involves a high-pressure wash down with chemicals or other cleaners, make sure to share details with the supplier.

6. What is the floor thickness required for your new equipment? Make sure you ask your supplier for the exact weight of your new equipment, robots will transmit extra forces to the floor while moving. Robotic equipment, for example, typically requires a minimum of 8 inches of additional floor reinforcement.

7. Stability is another factor to keep in mind for equipment that includes a robot, so be sure to think about anchorages. Robots can move very fast and equipment that incorporates them needs to stay steady. Are anchors included with the new equipment? If not, do you have all the anchors required for the new equipment?

8. Do you need to relocate piping or other items? Installing new equipment may force you to relocate existing components depending on the size and layout of the new equipment. Make sure that all relocating is done before installation begins, to avoid installation delay and production downtime.

9. Is lighting adequate for the new equipment? Consider alternative ways to provide light to the installation technician so he can do his job properly. You'll also need to think about the positioning of your current light fixtures. For example, if a new bagger is bigger or smaller than the existing one, the location of the light source that currently attaches to the bag magazine may not be optimally positioned once the new bagger is in place.

10. Do you have everything needed for equipment commissioning? Make a list of everything you need to do tests and to run your equipment. This may include empty bags, rolls of bag film, pallets, wrapping film, labels, labeller, printer and ink, glue, bagger, slip sheet, etc.

11. In case pre-installation preparation doesn't go as planned and you're not ready to install by the planned date, can equipment be stored for an extended period of time in a dry room without deteriorating? Find out if you have a dry place to store equipment, to prevent its deterioration.

12. Will you need an external contractor such as a millwright to perform mechanical installation? Ask your supplier if that service is included in your contract. If not, you'll need to hire an external contractor who can accommodate the installation schedule.

13. Do you need an external contractor to wire the new equipment?

14. Are cables included with your new equipment? Again, ask your supplier. You may need to buy cables elsewhere and have them on-site in time for installation.

15. When are the supplier's technicians available to supervise installation, commissioning and training? As soon as you know the delivery date, schedule these steps with the supplier's service technicians and the appropriate staff at your plant.

16. What is the size of the door or other access through which the equipment will be delivered? Before delivery, ask your supplier for the size of the largest piece of equipment. That way, you'll be able to identify the appropriate entrance for equipment delivery and prepare an alternative if the delivery areas you have are too small.

17. Do you have a forklift or equivalent tools to move the new equipment from the delivery truck to its destination inside the plant?

18. Other items and tools that might be needed for equipment handling or installation include ropes, crowbars, a welding machine, slings, etc. Ask your supplier what will be needed.

19. How much time is the production team giving you to remove existing equipment and install the new equipment? Do you have a "Plan B" in case installation or commissioning last longer than expected? Confirm the time needed with the project manager, and develop a backup plan.

20. Which spare parts need to be stocked? At a minimum, you will need a kit for commissioning.

21. Advise other teams at your plant that new equipment will be installed, and when. It is critically important to let your team know this because it may affect production for a few days. Alerting other team members also lets them know that they may be called upon to help you prepare.

22. Share your plant's internal safety procedures, safety training needs and all other internal standards with your supplier. Suppliers serve many clients and deal with multiple safety standards, so make sure that your supplier is aware of your plant's security rules so that they can follow them properly.

23. Do you need the supplier's installation personnel to take drug tests, acquire proof of insurance or meet other requirements of your insurance carrier? Find out from your insurance carrier and be sure to notify the supplier of any steps its personnel must take before they can work on your property.

24. Take part in the supplier's FAT (factory acceptance test) in your plant. This will enhance your understanding of the equipment and may raise questions you should ask. The goal is to avoid surprises at installation. Involve maintenance and production people if possible and keep production employees aware of and educated about the new equipment.

25. Schedule a post-installation follow-up visit with the supplier's technician. This will shorten the learning curve for your employees, and is even more important when you switch from manual to robotic/automatic equipment. Get all the information you need from your supplier; it wants to serve as a source of information and to partner with you to help you reach your goals.

26. Ask your supplier about preventive maintenance (PM): What needs to be performed, and how often? Inform your plant's Reliability Engineer that there is new equipment in need of PM. The supplier's Client Services team can tell you about all the steps in its after-sales support process.

27. Schedule training of all operators and maintenance personnel. If training is needed for night-shift employees, advise the supplier so that this training can be scheduled as well.project status reports

Project status reports are regular and formal. You will need to decide how often they are necessary depending on the size and nature of the project, it might be weekly, monthly or quarterly. In some situations reports might need to be hourly, if a problem is causing serious concern and has the potential to delay progress seriously. Daily reports might be necessary if there are implications for arranging work for the following day.

The degree of risk involved, and the time it would take to recover from failure to complete important milestones, are guides for deciding the frequency of reporting. Other considerations might include how quickly the project could get out of control, and the time it would take to implement contingency plans. The project sponsor may have a preference about the frequency of reports and review meetings.

To prepare the report, you will need to have information from the members of the project team on:

- completion of delegated tasks;
- completion of key stages;
- any work that is behind schedule (and why);
- any issues that need to be resolved (as soon as they arise);
- any difficulties anticipated in the near future.

Some project managers find a standard reporting template useful, so that team members can see at a glance what you need to know and just fill in the gaps. A standard report might include:

- the project title;
- a brief description of the key stage covered by the report;
- the name of the person responsible for this key stage;

- the date of the report;
- actual progress tracked against planned progress towards project 'milestones';
- a summary of progress on this key stage, including explanation of any slippage and remedial action taken;
- any issues awaiting resolution;
- the milestones due in the next reporting period and the date of the next report.

Once you have set up a system for regular reporting you will probably have to make sure that it happens, at least in the early stages. Be prepared to chase up reports and to insist that they are necessary and must be presented on time.

Risk and contingency planning

Risk is the chance of something occurring that has an adverse effect on the project. Many risks can be foreseen and identified. For example, if the project involves development of computer-based systems, time needs to be allowed for 'de-bugging' once the systems are installed.

The main categories of risk can be summarized as:

- **physical** loss of or damage to information, equipment or buildings as a result of an accident, fire or natural disasters;
- **technical** systems that do not work or do not work well enough to deliver the anticipated benefits;
- **labour** key people unable to contribute to the project because of, for example, illness, career change or industrial action;
- **political/social** for example withdrawal of support for the project as a result of change of government, a policy change by senior management, or protests from the community, the media, patients, service users or staff;
- **liability** legal action or the threat of it because some aspect of the project is considered to be illegal or because there may be compensation claims if something goes wrong.

Information to be shared within a limited group of stakeholders. Some stakeholders will only have an interest in the overview and the implications for the organization.

Self-Check - 4	Written Test

1. what are information required for preparation of report
2. write the main categories of risk
3. What question do you ask before any new equipment installation

. Answer the following question!

Note: Satisfactory rating 1 and 2 points   Unsatisfactory below 1 and 2 points

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

Score = ___________

Rating: ____________

- **Answer Sheet**
- Name: ________________________ Date: _______________

Information Sheet 5. Responding to unplanned Events/conditions

5.1 Responding to unplanned Events/conditions

Unplanned events are not expected to occur during the project's normal construction and operational phase activities. unplanned events. even with the best intentions, humans will occasionally make errors in judgement and/or decisions….and equipment will unexpectedly fail. these "unplanned events" do not occur very often, and thankfully most unplanned events are non-serious mishaps/ accidents with minor equipment/property damage and/or non-serious injuries. on more rare occasions, incidents can unfortunately result in property damage, serious injuries, and fatalities.
agency response. regardless of the intensity, unplanned events require a prompt, efficient, and effective response. the fs is committed to provide immediate assistance and support to the survivors, families, and coworkers of those who are fatally or seriously injured in the line of duty. our agency is also committed to learning and improving organizational performance. because of the low frequency and unpredictability of most unplanned events, agency administrators (aa) and employees are often confused and unsure as to the necessary steps to take after an event. appropriate actions of immediate and long term support will havee lasting effects

Accident severity

agency policy indicates that the level of appropriate agency response to unplanned events is determined by the severity and nature of the incident and preferences of the family. severity of unplanned events are categorized by the following distinctions:

1) Serious.

an unplanned event, or series of events, that resulted in any of the following:

- death….serious injury…. or occupational illness requiring treatment;
- substantial damage to, or loss of, equipment or property.

For operations, a serious accident/incident is defined in agency policy as an unplanned event (or series of events) that resulted in any of the following:

- one or more fatalities….or one or more personnel that required inpatient hospitalization (for other than observation) as a direct result of, or in support of, operations
- equipment or property loss, or consequences that the designated agency safety and health official (dasho), or designated agency official, judges to warrant a serious accident investigation.

2) Other than serious.

an unplanned event, or series of events, that resulted in any of the following:

- minor accident/incident….with minimal injury requiring minor or no treatment;
- minor property damage or equipment loss less than what is described under serious- but still requiring a response.

as many of the response actions, tasks, and responsibilities for serious and non-serious events overlap, we will not separate them here so as to reduce the length of this document. response actions listed here that are typically applicable to both serious and non-serious unplanned events will be indicated in the tables by the item number being underlined. actions required for each event are situational and made on a case-by-case basis.

initial response the initial response - immediate actions listed below take priority over normal official duties, and will continue until completed. their duration may last for several hours….often continuing well into the next section until initial response and follow-up is completed.

intial response actions listed below include the following primary tasks:

1) get medical and other requested help to the injured on-scene;

2) designate on-scene supervisor/coordinator and responsible official (fsh 1309.19)

3) assess & request needed resources & assistance to handle the original activity if applicable, and the unplanned event (incident-within-an-incident situation).

4) initiate unit emergency response plans and begin initial notifications;

initial response

- identify, select and use tools, equipment and material to complete tasks to specifications
- disconnect equipment and cables safely and in accordance with specifications
- handle material and equipment safely
- identify and report problems promptly and handle them as directed
- prepare equipment and storage site
- complete cleaning and storage related tasks in accordance with health and safety procedures
- perform inspection and quality checks - interpret and apply technical information to work activities
- demonstrate compliance with occupational health and safety regulations applicable to workplace operations
- show compliance with organizational quality procedures and processes within the context of disconnecting, cleaning and storing entertainment and events technology equipment

at the unconditioned events observed in the following aspects:

- demonstrate knowledge of the entertainment and events.technology equipment and associated disconnection, storage and cleaning requirements
- determine work requirements and plan and organize work to fulfill such requirements
- interactively communicate with others to ensure safe and effective opera

first 3 hours (following the initial incident)

These next actions are primarily organizational in nature and seek to establish a "team" of individuals who will be engaging to provide enhanced unplanned event response. team personnel will be assigned/delegated as needed, based on the situation. the appropriate response can expand just like an incident management team to meet the needs of the incident. each assigned/delegated position should follow the detailed duties/tasks and responsibilities listed in available references for their position.

first 3 hour response actions listed below include the following primary tasks:

1) assign/delegate personnel to fill key response positions;

2) Ensure unit emergency response plans are functioning, and both the unplanned event (or incident-within-an-incident) and the original activity/operations are being fully supported;

3) Documentation begins, information is relayed, and all initial notifications have been made

First 24 hours (following the initial incident)

All initial response - immediate actions and first 3 hour actions listed above should have been initiated and will continue until completed. their duration may extend for many hours and well into the next section. specific tasks/duties for each assigned/delegated role become numerous after the first few hours, and personnel will need to review the duties and tasks identified for their specific role/position as found within the reference documents.

first 24 hour response actions listed below include the following primary tasks:

1) ensure all notifications are made & distribute updated information through channels;

2) coordinate and support partners and assigned/delegated response positions;

3) contact off unit agency entities for assistance

Beyond 24 hours (following the initial incident)

All first 3 & 24 hour actions listed above should have been initiated and will continue until completed. their duration may extend for many hours or even days.   as most response actions have now been initiated, focus will begin to transition to establishing and enhancing the support entities either on scene or ordered and enroute to the incident/unit.

<u>Beyond 24 hour</u> response actions listed below include the following primary tasks:

1) provide adequate help to maintain unit services and conclude incident activities;

2) continue support and follow-up to meet the needs and wishes of the families;

3) take additional actions needed to support co-workers and incoming resources record keeping documentation is a very important administrative requirement for unplanned event response. there are many aspects of records management to be aware of, including records creation, maintenance, file designations and disposition, records management in emergency operations, foia requests, and management of special records. consider using a response log form to document response actions taken.

Self-Check 5	Written Test

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

<u>Directions</u>: For the following questions, say TRUE if the statement

is correct and FALSE if it is incorrect (wrong).

1 Interactively communicate with others to ensure safe and effective operations is available if unplanned condition is happen
2 Perform inspection is available to responding unplanned events.
3 Unconditioned events observed in the handle material and equipment safely.

. Answer the following question!

Note: Satisfactory rating 4and 6 points Unsatisfactory below 4and 6 points

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

Score = ____________
Rating: ______________

Answer Sheet

Name: ___________________________ Date: _____________

Operation title: - I/O Connection to LOGO unit

Purpose	**To acquire the trainees with I/O Connection to LOGO unit**
Equipment ,tools and materials	Supplies and equipment needed or useful for I/O Connection to LOGO unit include these: • Logo PLC • Push button • Contactors • I/O device • screw driver • Diagonal side cutter • Pliers • Digital Multi-tester • various instrument and control device
Conditions or situations for the operations	• All tools, equipment's and materials should be available on time when required. Appropriate material, working area/ workshop to connect I/ O to logo PLC

Procedures	1. Apply OH &S PPE 2. Identify instrumentation and control devices 3. Take LOGO PLC 4. Take all necessary hand tools and accessories. 5. Using multimeter, check each device 6. Report your findings to your instructor 7. Record the result
Precautions	• Care should be taken while connecting with electric power, assembling, fitting and logo PLC • Preparing materials, tools and equipment are according to inseminator command.
Quality criteria	• Did personal protective equipment worn 8. Did trainees Identify instrumentation and control devices 9. Did the trainee Take LOGO PLC 10.. Checks the circuit safely using proper instrument 11. Installs electrical wiring according to the job requirements 12. Did the trainees report your findings to your instructor

I/O Connection to LOGO unit

LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions:

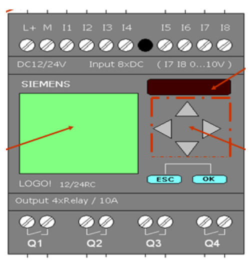
1. You are required to perform any of the following:

1.1. Prepare equipment and material used for connecting I/ O to logo PLC

1.2. Connect I/ O to logo PLC

2. Request your teacher for evaluation and feedback

LOGO Unit:-



LG #28	LO3. Create/Modify, install and test basic PLC program
Instruction sheet	

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

- Understanding basic PLC Programming
- Using appropriate Programming language
- Reading PLC diagrams and work instruction
- Testing Created/Modified basic PLC programs
- Reviewing tested process to ensure defect-free PLC program Text Processes
- Creating/Preparing External documentation and back-up programs

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:

- Understanding basic PLC Programming
- Use appropriate Programming language
- Read PLC diagrams and work instruction
- Test Created/Modified basic PLC programs
- Review tested process to ensure defect-free PLC program Text Processes
- Create /Prepare External documentation and back-up programs

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. Using appropriate Programming language

2.1.1 Standard Programming language

A programming language is a formal computer language designed to communicate instructions to a machine, particularly a computer. Programming languages can be used to create programs to control the behavior of a machine or to express algorithms.

Ladder and Functional Block Programming

Programs for microprocessor-based systems have to be loaded into them in machine code, this being a sequence of binary code numbers to represent the program instructions. However, assembly language based on the use of mnemonics can be used, e.g. LD is used to indicate the operation required to load the data that follows the LD, and a computer program called an assembler is used to translate the mnemonics into machine code.

However, the use of these methods to write programs requires some skill in programming and PLCs are intended to be used by engineers without any great knowledge of programming. As a consequence, ladder programming was developed. This is a means of writing programs which can then be converted into machine code by some software for use by the PLC microprocessor.

This method of writing programs became adopted by most PLC manufacturers, however each tended to have developed their own versions and so an international standard has been adopted for ladder programming and indeed all the methods used for programming PLCs.

The standard, published in 1993, is IEC 1131-3 (International Electro-technical Commission).

The IEC 1131-3 programming languages are:

- Ladder Diagrams (LAD)

- Instruction List (IL)
- Sequential Function Charts (SFC)
- Structured Text (ST)and
- Function Block Diagrams (FBD).

Instruction List (IL)– low - level programming language similar to Assembler

Ladder Diagram (LD)– graphical language based on rules of the electrical circuits with wires , relays , etc.

Function Block Diagram (FBD)– graphical language with the possibilities to implement complex control and numerical functions in a simple way . User can use provided function blocks grouped in libraries and create custom blocks (written in any of the IEC 61131 - 3 compliant languages) to build a control algorithm.

Structured Text (ST) – text language similar in its syntax to Pascal and Basic ; effective solution for every complex control algorithm

Sequential Function Chart (SFC)– graphical language describing operation of the process and machine . This is the only language in the IEC 61131 - 3 standard that depends on usage of at least one other language from the list. **SFC** is used to create a state machine of the process ; each state is created with another language , such as ST or IL.

Ladder Diagrams

As an introduction to ladder diagrams, consider the simple wiring diagram for an electrical circuit in Fig :(a). The diagram shows the circuit for switching on or off an electric motor. We can redraw this diagram in a different way, using two vertical lines to represent the input power rails and stringing the rest of the circuit between them. Fig:(b) shows the result. Both circuits have the switch in series with the motor and supplied with electrical power when the switch is closed. The circuit shown in Fig:(b) is termed a **ladder diagram**.

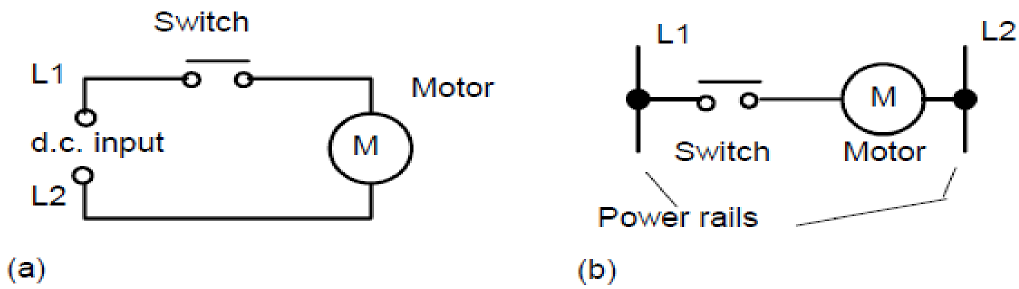


Fig 40 Ways of drawing the same electrical circuit

With such a diagram the power supply for the circuits is always shown as two vertical lines with the rest of the circuit as horizontal lines. The power lines, or rails as they are often termed, are like the vertical sides of a ladder with the horizontal circuit lines like the rungs of the ladder. The horizontal rungs show only the control portion of the circuit, in the case of Fig : it is just the switch in series with the motor. Circuit diagrams often show the relative physical location of the circuit components and how they are actually wired. With ladder diagrams no attempt is made to show the actual physical locations and the emphasis is on clearly showing how the control is exercised.

Fig below shows an example of a ladder diagram for a circuit that is used to start and stop a motor using push buttons. In the normal state, push button 1 is open and push button 2 closed. When button 1 is pressed, the motor circuit is completed and the motor starts. Also, the holding contacts wired in parallel with the motor close and remain closed as long as the motor is running. Thus when the push button 1 is released, the holding contacts maintain the circuit and hence the power to the motor.

To stop the motor, button 2 is pressed. This disconnects the power to the motor and the holding contacts open. Thus when push button 2 is released, there is still no power to the motor. Thus we have a motor which is started by pressing button 1 and stopped by pressing button 2.

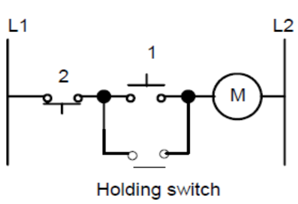


Fig 41 Stop-start switches

PLC ladder programming

A very commonly used method of programming PLCs is based on the use of ladder diagrams. Writing a program is then equivalent to drawing a switching circuit. The ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines, i.e. the rungs of the ladder, between these two verticals.

In drawing a ladder diagram, certain conventions are adopted:

The vertical lines of the diagram represent the power rails between which circuits are connected. The power flow is taken to be from the left-hand vertical across a rung.

Each rung on the ladder defines one operation in the control process.

A ladder diagram is read from left to right and from top to bottom,

Figure 40: showing the scanning motion employed by the PLC.

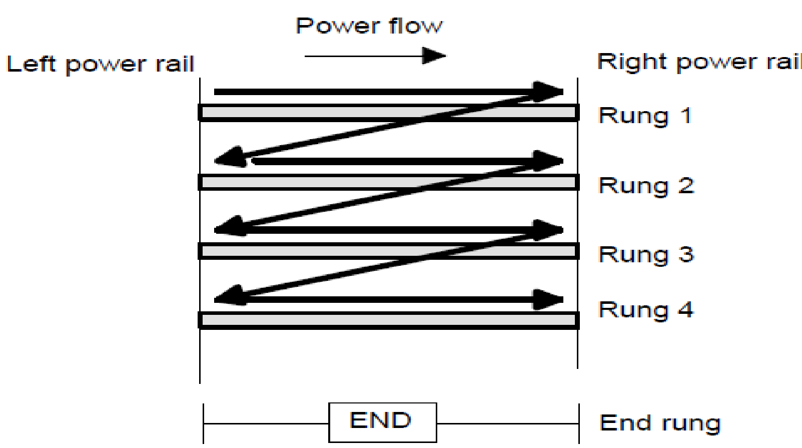


Fig 41 scanning the ladder program

The top rung is read from left to right. Then the second rung down is read from left to right and so on. When the PLC is in its run mode, it goes through the entire ladder program to the end, the end rung of the program being clearly denoted, and then promptly resumes at the start. This procedure of going through all the rungs of the program is termed a cycle. The end rung might be indicated by a block with the word END or RET for return, since the program promptly returns to its beginning.

Each rung must start with an input or inputs and must end with at least one output. The term input is used for a control action, such as closing the contacts of a switch, used as an input to the PLC. The term output is used for a device connected to the output of a PLC, e.g. a motor.

Electrical devices are shown in their normal condition. Thus a switch which is normally open until some object closes it, is shown as open on the ladder diagram. A switch that is normally closed is shown closed.

A particular device can appear in more than one rung of a ladder. For example, we might have a relay which switches on one or more devices. The same letters and/or numbers are used to label the device in each situation.

The inputs and outputs are all identified by their addresses, the notation used depending on the PLC manufacturer.

Fig shows standard IEC 1131-3 symbols that are used for input and output devices. Some slight variations occur between the symbols when used in semi-graphic form and when in full graphic. Note that inputs are represented by different symbols representing normally open or normally closed contacts. The action of the input is equivalent to opening or closing a switch. Output coils are represented by just one form of symbol.

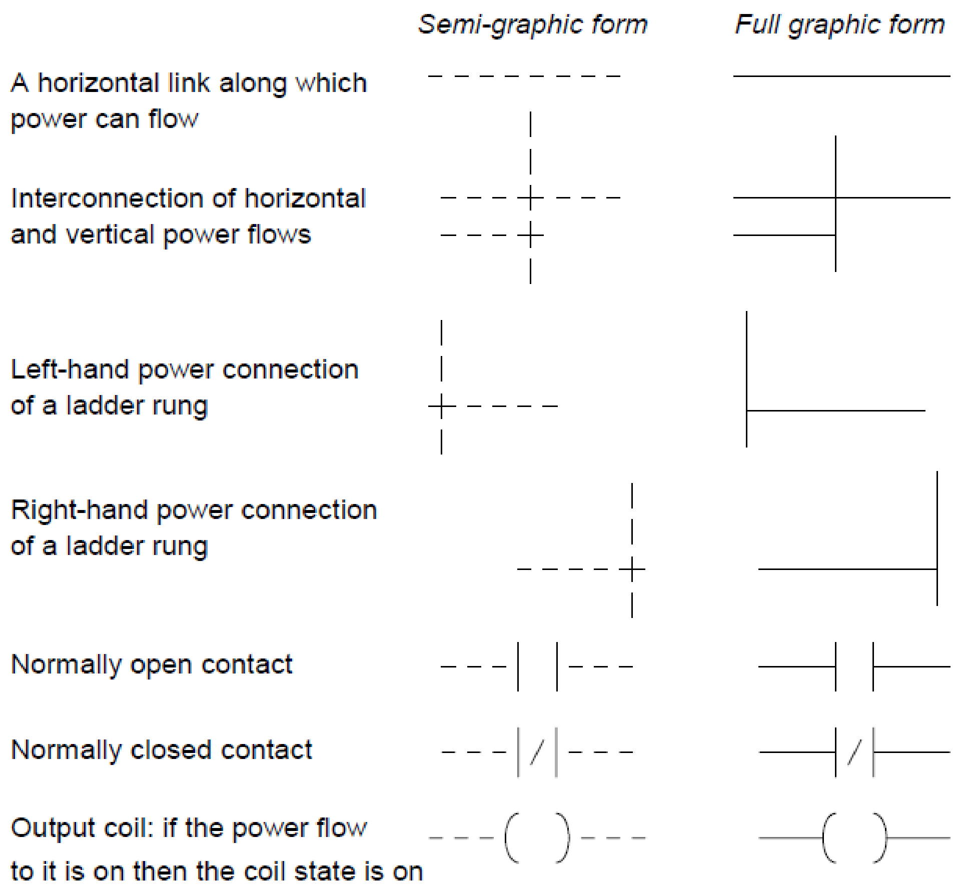


Fig 42 Basic symbols for input and output devices

Behind the ladder logic

So what logic can ladder logic actually perform? With the increasing demand for functionality and ease of use, many of today's PLCs incorporate function blocks with ladder logic. The structure of the program is still ladder with the more complex instructions being function blocks. So to answer the question, let's look at a few examples:

Boolean Logic: The ON/OFF, TRUE/FALSE algebra of binary systems, the basics of which are AND, OR and NOT operators. To put it simply, rung 5 in our code needs CR1(C1) AND CR2(C2) to turn ON motor M1 (Y002).

Timing: Timer instructions are available to allow for on-delayed or off-delayed events. Once triggered, the timer will turn its associated output ON (on-delay) or OFF (off-delay) after the set time has elapsed.

Counting: Count-up and count-down functions increase or decrease the counter value on every transition of the input.

Comparisons: Compare instructions are available to determine if values are less than, equal to or greater than each other. Math: These instructions not only allow for the simple addition and subtraction but also for more complex operations like tangents, square roots, etc. Special functions: These include PID loops, communication instructions, shift registers, drum sequencers, ramp generators, etc.

Function Blocks Diagram (FBD)

The term function block diagram (FBD) is used for PLC programs described in terms of graphical blocks. It is described as being a graphical language for depicting signal and data flows through blocks, these being reusable software elements. A function block is a program instruction unit which, when executed, yields one or more output values. Thus a block is represented in the manner shown in Figure 42: with the function name written in the box.

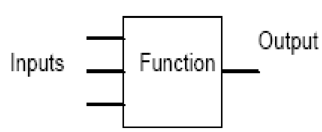


Fig 43 Function block

A function block is depicted as a rectangular block with inputs entering from the left and outputs emerging from the right. The function block type name is shown in the block, e.g. AND, with the name of the function block in the system shown above it, Timer1. Names of function block inputs are shown within the block at the appropriate input and output points. Cross diagram connectors are used to indicate where graphical lines would be difficult to draw without cluttering up or complicating a diagram and show where an output at one point is used as an input at another.

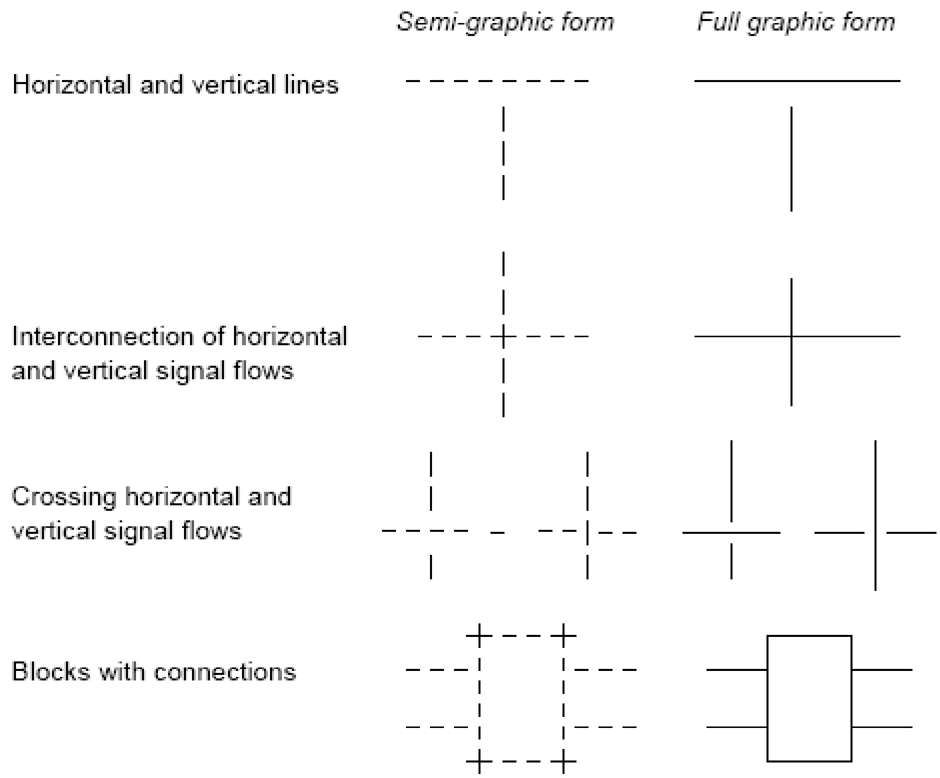


Fig44 Function block diagrams representation

Conversion of Schematic wiring diagrams in to Ladder and Functional Block diagrams

Example 1. Hard wiring ➞ LAD ➞ FBD

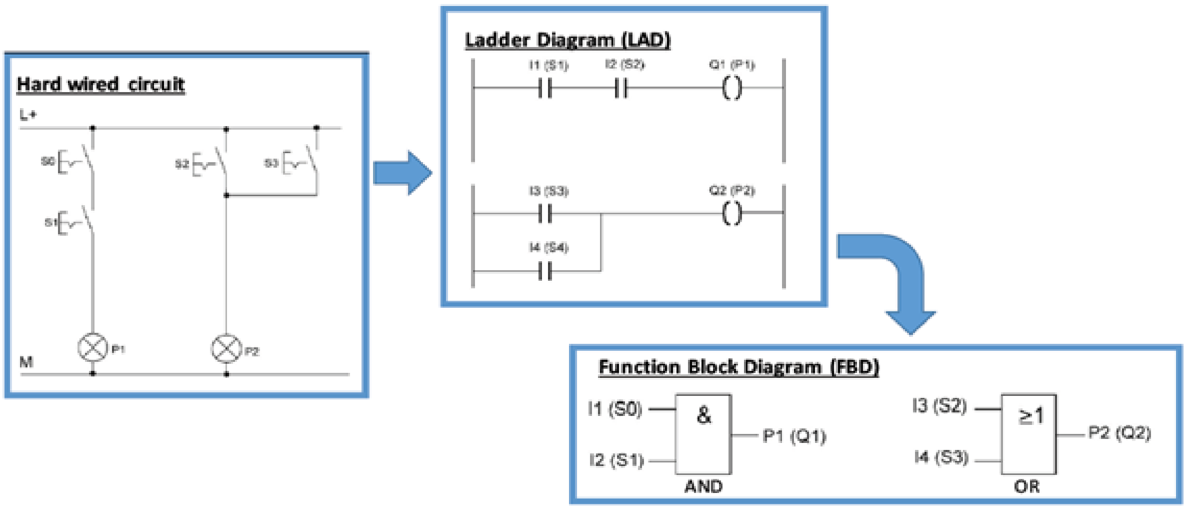


Fig 45 wiring diagrams in to Ladder and Functional Block diagrams

Example 2: forward Reverse starting of 3-phase induction motor with auxiliary (electrical) interlocking system

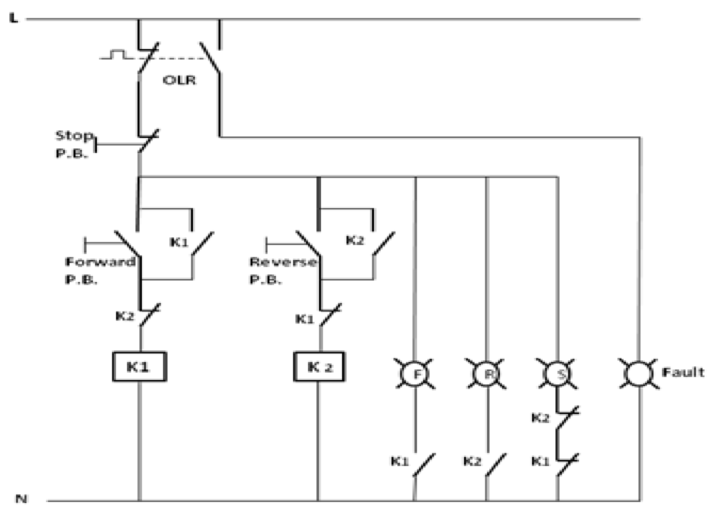


Fig 46 Hard wiring diagram for example 2

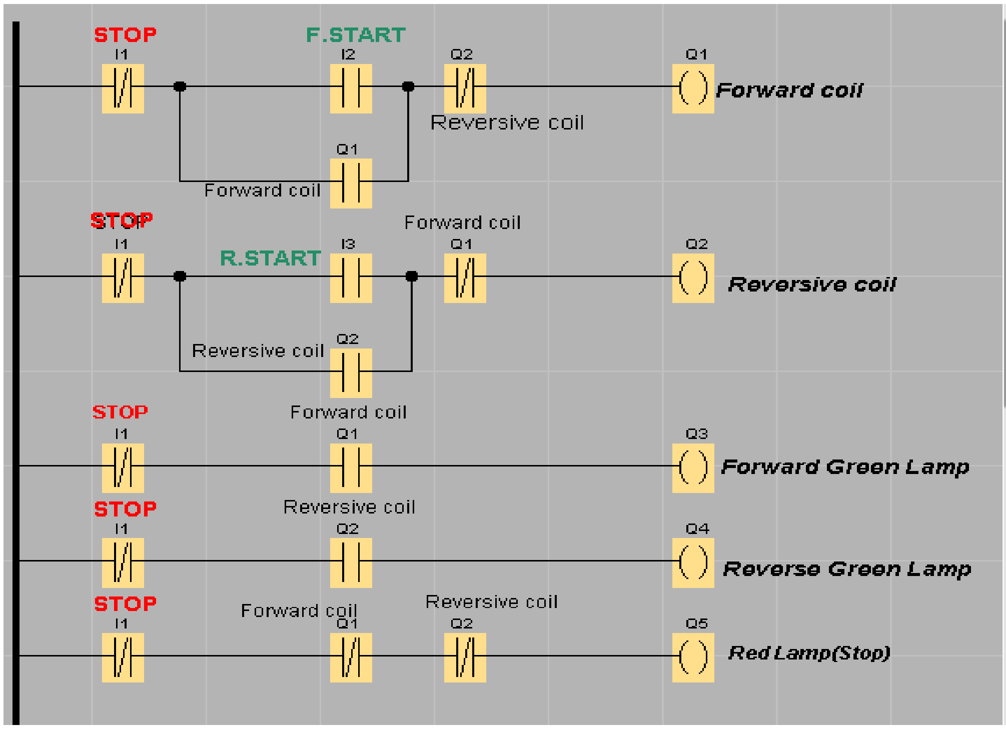


Fig Ladder Diagram for example 2

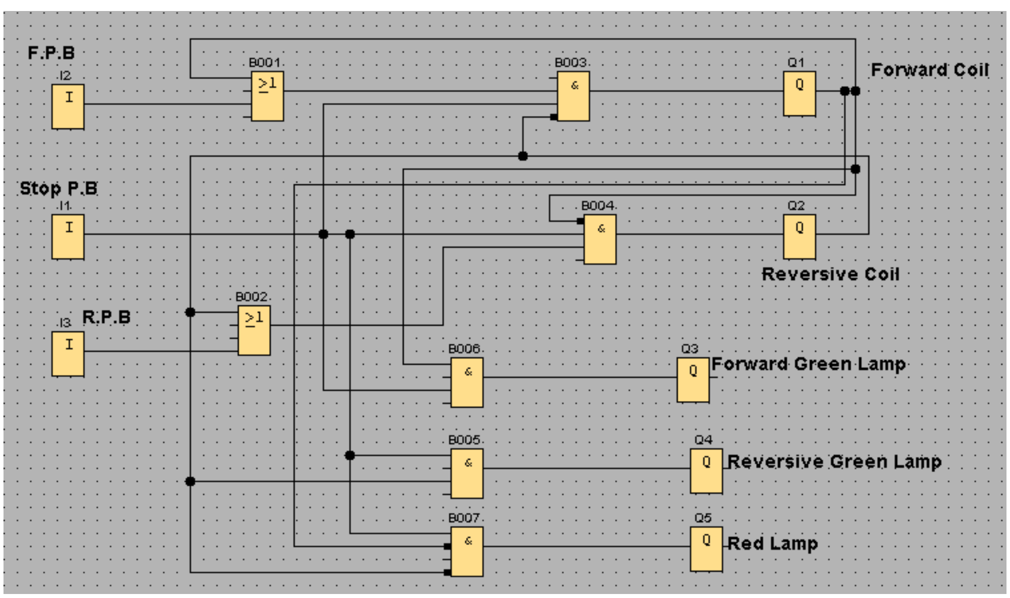


Fig 47 Functional Block Diagram for example 2

Excusion of ladder logic

Typically before starting to execute the logic, the CPU reads the physical inputs tied to the I/O modules to update their status in the CPU's memory table. Then, starting at the top left of the program, the CPU works its way down the rail executing each rung or sub rung from left to right. So if PB1 is pressed, the CPU will turn ON CR1. Since CR1 has changed states, in rung 3 the CPU will activate CR3. CR3's normally-closed state is used in rung 4, so the CPU will then turn OFF L1.

Even though we still refer to coils and contacts in ladder logic, remember that they are memory representations, not actual devices. Once the CPU reaches the last rung it will update the real world outputs, then loop back and run it all again. This process will continue as long as the CPU is powered and in the RUN mode. The time it takes the CPU to execute one pass and loop back to the beginning is known as scan time. Scan time can be important to applications where timing is critical. Subroutines and special purpose I/O modules can be used to help reduce the scan time if needed.

Mnemonics

1) In general, a mnemonic (from Greek mnemon or mindful; pronounced neh-MAHN-ik) is a memory aid, such as an abbreviation, rhyme or mental image that helps to remember something. The technique of developing these remembering devices is called "mnemonics."

2) In computer assembler (or assembly) language, a mnemonic is an abbreviation for an operation. It's entered in the operation code field of each assembler program instruction.

For example, on an Intel microprocessor, inc ("increase by one") is a mnemonic. On an IBM System/370 series computer, BAL is a mnemonic for "branch-and-link."

Mnemonic Instruction

There are other methods to program PLCs. One of the earliest techniques involved mnemonic instructions. These instructions can be derived directly from the ladder logic diagrams and entered into the PLC through a simple programming terminal.

The mnemonics codes used by different PLC manufactures differ but an international standard (IEC 1131-3) has been proposed and is widely used Table below shows core mnemonics. For the rest of the following instructions, Mitsubishi mnemonics will be used

Some Instruction code mnemonics

Table 3 mnemonic instruction

IEC 1131-3	Mitsubishi	OMRON	Siemens	Operation	Ladder diagram
LD	LD	LD	A	Load operand into result register	Start a rung with open contacts
LDN	LDI	LD NOT	AN	Load negative operand into result register	Start a rung with closed contacts
AND	AND	AND	A	Boolean AND	A series element with open contacts
ANDN	ANI	AND NOT	AN	Boolean AND with negative operand	A series element with closed contacts
OR	OR	OR	O	Boolean OR	A parallel element with open contacts
ORN	ORI	OR NOT	ON	Boolean OR with negative operand	A parallel element with closed contacts
ST	OUT	OUT	=	Store result register into operand	An output from a rung

2.1.2 Procedure language

A **procedural language** is a computer programming language that follows, in order, a set of commands. Examples of computer procedural languages are BASIC, C, FORTRAN, Java, and Pascal.

Procedural languages are some of the common types of programming languages used by script and software programmers. They make use of functions, conditional statements, and variables to create programs that allow a computer to calculate and display a desired output.

Using a procedural language to create a program can be accomplished by using a programming editor or IDE, like Adobe Dreamweaver, Eclipse, or Microsoft Visual Studio. These editors help users develop programming code using one or more procedural languages, test the code, and fix bugs in the code.

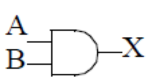
.

BOOLEAN ALGEBRA

Boolean algebra was developed in the 1800's by James Bool, an Irish mathematician.
It was found to be extremely useful for designing digital circuits, and it is still heavily used by electrical engineers and computer scientists. The techniques can model a logical system with a single equation. The equation can then be simplified and/or manipulated into new forms. The same techniques developed for circuit designers adapt very well to ladder logic programming.
Boolean equations consist of variables and operations and look very similar to normal algebraic equations. The three basic operators are AND, OR and NOT; more complex operators include exclusive or (EOR), not and (NAND), not or (NOR). Small truth tables for these functions are shown in Figure 20:. Each operator is shown in a simple equation with the variables A and B being used to calculate a value for X. Truth tables are a simple (but bulky) method for showing all of the possible combinations that will turn an output on or off.

Note: By convention a false state is also called off or 0 (zero). A true state is also called on or 1.

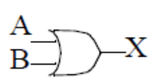
AND



$X = A \cdot B$

A	B	X
0	0	0
0	1	0
1	0	0
1	1	1

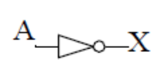
OR



$X = A + B$

A	B	X
0	0	0
0	1	1
1	0	1
1	1	1

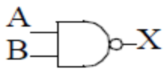
NOT



$X = \overline{A}$

A	X
0	1
1	0

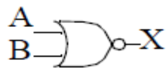
NAND



$X = \overline{A \cdot B}$

A	B	X
0	0	1
0	1	1
1	0	1
1	1	0

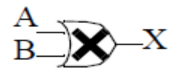
NOR



$X = \overline{A + B}$

A	B	X
0	0	1
0	1	0
1	0	0
1	1	0

EOR



$X = A \oplus B$

A	B	X
0	0	0
0	1	1
1	0	1
1	1	0

Note: The symbols used in these equations, such as + for OR are not universal standards and some authors will use different notations.

Note: The EOR function is available in gate form, but it is more often converted to its equivalent, as shown below.

$$X = A \oplus B = A \cdot \overline{B} + \overline{A} \cdot B$$

Fig 48 Boolean Operations with Truth Tables and Gates

In a Boolean equation the operators will be put in a more complex form as shown in Fig : The variable for these equations can only have a value of 0 for false, or 1 for true. The solution of the equation follows rules similar to normal algebra. Parts of the equation inside parenthesis are to be solved first. Operations are to be done in the sequence NOT, AND, OR. In the example the NOT function for C is done first, but the NOT over the first set of parentheses must wait until a single value is available. When there is a choice the AND operations are done before the OR operations. For the given set of variable values the result of the calculation is false.

given

$$X = \overline{(A + B \cdot C)} + A \cdot (B + \overline{C})$$

assuming A=1, B=0, C=1

$$X = \overline{(1 + 0 \cdot 1)} + 1 \cdot (0 + \overline{1})$$

$$X = \overline{(1 + 0)} + 1 \cdot (0 + 0)$$

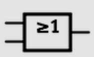
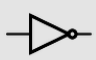
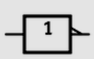
$$X = \overline{(1)} + 1 \cdot (0)$$

$$X = 0 + 0$$

$$X = 0$$

Fig 49 A Boolean Equation

Ladder programs can be derived from Boolean expressions since we are concerned with a mathematical system of logic. In Boolean algebra there are just two digits, 0 and 1. When we have an AND operation for inputs A and B then we can write:

Type	Distinctive shape	Rectangular shape	Boolean algebra between A & B	Truth table
AND			$A \cdot B$	INPUT: A, B / OUTPUT: A AND B 0 0 → 0 0 1 → 0 1 0 → 0 1 1 → 1
OR			$A + B$	INPUT: A, B / OUTPUT: A OR B 0 0 → 0 0 1 → 1 1 0 → 1 1 1 → 1
NOT			$\overline{A}$	INPUT: A / OUTPUT: NOT A 0 → 1 1 → 0

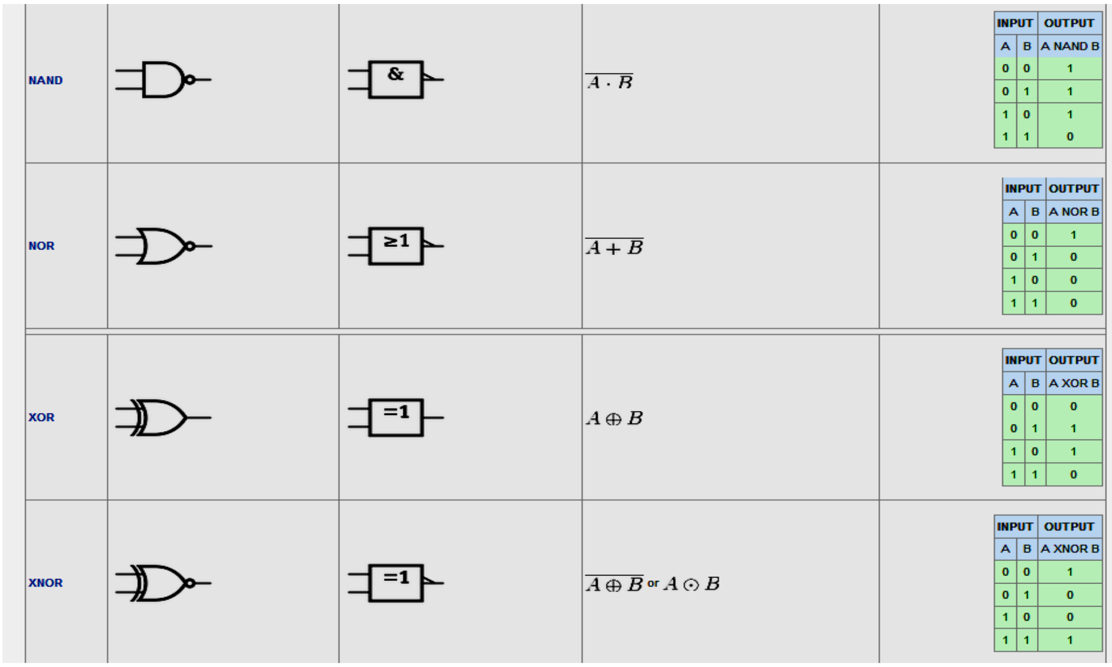


Fig 50 Boolean expressions

Introduction to Number Systems

Different characteristics that define a number system include the number of independent digits used in the number system, the place values of the different digits constituting the number and the maximum numbers that can be written with the given number of digits. Among the three characteristic parameters, the most fundamental is the number of independent digits or symbols used in the number system. It is known as the radix or base of the number system. The decimal number system with which we are all so familiar can be said to have a radix of 10 as it has 10 independent digits, i.e. 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9.

Similarly, the binary number system with only two independent digits, 0 and 1, is a radix-2 number system. The octal and hexadecimal number systems have a radix (or base) of 8 and 16 respectively.

We will see in the following sections that the radix of the number system also determines the other two characteristics. The place values of different digits in the integer part of the number are given by r^0, r^1, r^2, r^3 and so on, starting with the digit adjacent to the radix point. For the fractional part, these are r^{-1}, r^{-2}, r^{-3} and so on, again starting with the digit next to the radix point. Here, r is the radix of the number system. Also, maximum numbers that can be written with n digits in a given number system are equal to r^n.

Decimal Number System

The decimal number system is a radix-10 number system and therefore has 10 different digits or symbols. These are 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. All higher numbers after '9' are represented in terms of these 10 digits only. The process of writing higher-order numbers after '9' consists in writing the second digit (i.e. '1') first, followed by the other digits, one by one, to obtain the next 10 numbers from '10' to '19'. The next 10 numbers from '20' to '29' are obtained by writing the third digit (i.e. '2') first, followed by digits '0' to '9', one by one. The process continues until we have exhausted all possible two-digit combinations and reached '99'. Then we begin with three-digit combinations. The first three-digit number consists of the lowest two-digit number followed by '0' (i.e. 100), and the process goes on endlessly.

The place values of different digits in a mixed decimal number, starting from the decimal point, are 10^0, 10^1, 10^2 and so on (for the integer part) and 10^{-1}, 10^{-2}, 10^{-3} and so on (for the fractional part).

The value or magnitude of a given decimal number can be expressed as the sum of the various digits multiplied by their place values or weights.

As an illustration, in the case of the decimal number 3586.265, the integer part (i.e. 3586) can be expressed as $3586 = 6\times10^0 + 8\times10^1 + 5\times10^2 + 3\times10^3 = 6+80+500+3000 = 3586$ and the fractional part can be expressed as $265 = 2\times10^{-1} + 6\times10^{-2} + 5\times10^{-3} = 0.2+0.06+0.005 = 0.265$.

We have seen that the place values are a function of the radix of the concerned number system and the position of the digits. We will also discover in subsequent sections that the concept of each digit having a place value depending upon the position of the digit and the radix of the number system is equally valid for the other more relevant number systems.

Binary Number System

The binary number system is a radix-2 number system with ‘0’ and ‘1’ as the two independent digits. All larger binary numbers are represented in terms of ‘0’ and ‘1’. The procedure for writing higher order binary numbers after ‘1’ is similar to the one explained in the case of the decimal number system.

For example, the first 16 numbers in the binary number system would be 0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011, 1100, 1101, 1110 and 1111. The next number after 1111 is 10000, which is the lowest binary number with five digits. This also proves the point made earlier that a maximum of only 16 (= 2^4) numbers could be written with four digits. Starting from the binary point, the place values of different digits in a mixed binary number are 2^0, 2^1, 2^2 and so on (for the integer part) and 2^{-1}, 2^{-2}, 2^{-3} and so on (for the fractional part).

Octal Number System

The octal number system has a radix of 8 and therefore has eight distinct digits. All higher-order numbers are expressed as a combination of these on the same pattern as the one followed in the case of the binary and decimal number systems described above.

The independent digits are 0, 1, 2, 3, 4, 5, 6 and 7. The next 10 numbers that follow ‘7’, for example, would be 10, 11, 12, 13, 14, 15, 16, 17, 20 and 21. In fact, if we omit all the numbers containing the digits 8 or 9, or both, from the decimal number system, we end up with an octal number system. The place values for the different digits in the octal number system are 8^0, 8^1, 8^2 and so on (for the integer part) and 8^{-1}, 8^{-2}, 8^{-3} and so on (for the fractional part).

Hexadecimal Number System

The hexadecimal number system is a radix-16 number system and its 16 basic digits are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E and F. The place values or weights of different digits in a mixed hexadecimal number are 16^0, 16^1, 16^2 and so on (for the integer part) and 16^{-1}, 16^{-2}, 16^{-3} and so on (for the fractional part). The decimal equivalent of A, B, C, D, E and F are 10, 11, 12, 13, 14 and 15 respectively, for obvious reasons.

The hexadecimal number system provides a condensed way of representing large binary numbers stored and processed inside the computer. One such example is in representing addresses of different memory locations. Let us assume that a machine has 64K of memory. Such a memory has 64K (= 2^{16} = 65 536) memory locations and needs 65 536 different addresses. These addresses can be designated as 0 to 65 535 in the decimal number system and 00000000 00000000 to 11111111 11111111 in the binary number system. The decimal number system is not used in computers and the binary notation here appears too bulky and inconvenient to handle. In the hexadecimal number system, 65 536 different addresses can be expressed with four digits from 0000 to **FFFF**. Similarly, the contents of the memory when represented in hexadecimal form are very convenient to handle.

Data Organization

Binary digit (Bits)

Bit is an abbreviation of the term 'binary digit' and is the smallest unit of information. It is either '0' or '1'. A groups of four bits (called nibbles). A byte is a string of eight bits and groups of 16 bits (called words). The byte is the basic unit of data operated upon as a single unit in computers. A computer word is again a string of bits whose size, called the 'word length' or 'word size', is fixed for a specified computer, although it may vary from computer to computer.

- **1's and 2's Complement**

These are the complements used for binary numbers. Their representation is very important as digital systems work on binary numbers only.

- **1's Complement**

1's complement of a binary number is obtained simply by replacing each 1 by 0 and each 0 by 1. Alternately, 1's complement of a binary can be obtained by subtracting each bit from 1.

Example. Find 1's complement of (i) 011001 (ii) 00100111

Solution. (i) Replace each 1 by 0 and each 0 by 1

0 1 1 0 0 1

1 0 0 1 1 0

So, 1's complement of 011001 is 100110.

(ii) Subtract each binary bit from 1.

1 1 1 1 1 1 1 1

–0 0 1 0 0 1 1 1

1 1 0 1 1 0 0 0 ← 1's complement

one can see that both the method gives same result.

Exercise: Find the 1's complement of $(10010110)_2$.

- **2's Complement**

2's complement of a binary number can be obtained by adding 1 to its 1's complement.

Example. Find 2's complement of (i) 011001 (ii) 0101100

Solution. (i) 0 1 1 0 0 1 Number

1 0 0 1 1 0 1's complement

+ 1 Add 1 to 1's complement

1 0 0 1 1 1 2's complement

(ii) 0 1 0 1 1 0 0 Number

1 0 1 0 0 1 1 1's complement

+ 1 Add 1 to 1's complement

1 0 1 0 1 0 0 2's complement

Exercise: Find the 2's complement of $(10010110)_2$.

Decimal Number System

- **9's and 10's Complement**

9's and 10's complements are the methods used for the representation of decimal numbers.

They are identical to the 1's and 2's complements used for binary numbers.

- ✓ **9's complement:** 9's complement of a decimal number is defined as $(10^n - 1) - N$, where n is no. of digits and N is given decimal numbers. Alternately, 9's complement of a decimal number can be obtained by subtracting each digit from 9.

9's complement of N = $(10^n - 1) - N$.

Example. Find out the 9's complement of following decimal numbers.

(i) 459 *(ii) 36* *(iii) 1697*

Solution. (*i*) By using $(10^n-1) - N$; But, $n = 3$ in this case

So, $(10^n-1) - N = (10^3 - 1) - 459 = 540$

Thus 9's complement of 459 = 540

(*ii*) By subtracting each digit from 9

$$\begin{array}{r} 9\ 9 \\ -3\ 6 \\ \hline 6\ 3 \\ \hline \end{array}$$

So, 9's complement of 36 is 63.

(*iii*) We have $N = 1697$, so $n = 4$

Thus, $10^n-1 = 10^4 - 1 = 9999$

So, $(10^n-1) - N = (10^4-1) - 1697 = 9999 - 1697$

$= 8302$

Thus, 9's complement of 1697 = 8302

Exercise: Find the 9's complement of $(2496)_{10}$.

- ✓ **10's complement:** 10's complement of a decimal number is defined as $10^n - N$.

10's complement of N = 10^n – N

but

$10^n - N = (10^n - 1) - N + 1$

= 9's complement of N + 1

Thus, 10's complement of a decimal number can also be obtained by adding 1 to its 9's complement.

Example. Find out the 10's complement of following decimal numbers. (i) 459 (ii) 36.

Solution. (i) By using 10^n – N; We have N = 459 so n = 3

So, $10^n - N = 10^3 - 459 = 541$

So, 10's is complement of 459 = 541

(ii) By adding 1 to 9's complement

9's complement of 36 = 99 – 36

= 63

Hence, 10's complement of 36 = 63 + 1

= 64

Exercise: Find the 10's complement of $(2496)_{10}$.

Octal Number System

In the octal number system, we have the 7's and 8's complements. The 7's complement of a given octal number is obtained by subtracting each octal digit from 7. For example, the 7's complement of $(562)_8$ would be $(215)_8$. The 8's complement is obtained by adding '1' to the 7's complement. The 8's complement of $(562)_8$ would be $(216)_8$.

Hexadecimal Number System

The 15's and 16's complements are defined with respect to the hexadecimal number system. The 15's complement is obtained by subtracting each hex digit from 15. For example, the 15's complement of $(3BF)_{16}$ would be $(C40)_{16}$. The 16's complement is obtained by adding '1' to the 15's complement. The 16's complement of $(2AE)_{16}$ would be $(D52)_{16}$.

Binary-to-Decimal Conversion

The decimal equivalent of the binary number $(1001.0101)_2$ is determined as follows:

- The integer part = 1001

The decimal equivalent = $1 \times 2^0 + 0 \times 2^1 + 0 \times 2^2 + 1 \times 2^3 = 1 + 0 + 0 + 8 = 9$

• The fractional part = .0101

The decimal equivalent = $0 \times 2^{-1} + 1 \times 2^{-2} + 0 \times 2^{-3} + 1 \times 2^{-4} = 0 + 0.25 + 0 + 0.0625 = 0.3125$

• Therefore, the decimal equivalent of $(1001.0101)_2 = 9.3125$

Octal-to-Decimal Conversion

The decimal equivalent of the octal number $(137.21)_8$ is determined as follows:

• The integer part = 137

The decimal equivalent = $7 \times 8^0 + 3 \times 8^1 + 1 \times 8^2 = 7 + 24 + 64 = 95$

• The fractional part = .21

The decimal equivalent = $2 \times 8^{-1} + 1 \times 8^{-2} = 0.265$

• Therefore, the decimal equivalent of $(137.21)_8 = (95.265)_{10}$

Hexadecimal-to-Decimal Conversion

The decimal equivalent of the hexadecimal number $(1E0.2A)_{16}$ is determined as follows:

• The integer part = 1E0

The decimal equivalent = $0 \times 16^0 + 14 \times 16^1 + 1 \times 16^2 = 0 + 224 + 256 = 480$

• The fractional part = 2A

The decimal equivalent = $2 \times 16^{-1} + 10 \times 16^{-2} = 0.164$

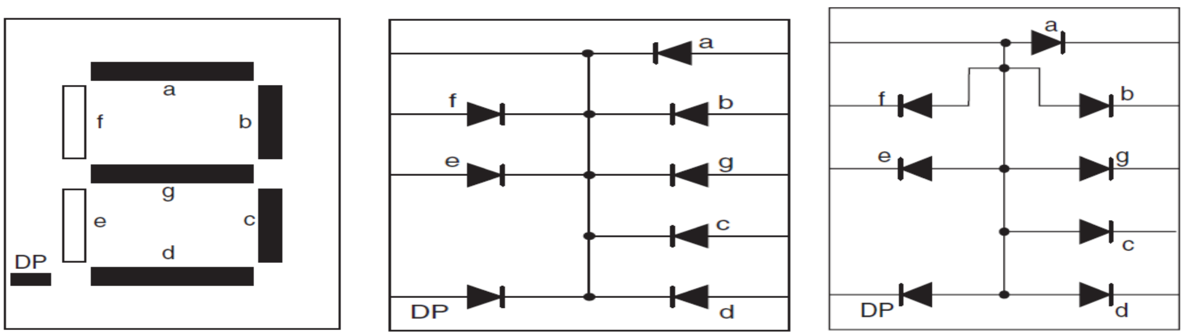
• Therefore, the decimal equivalent of $(1E0.2A)_{16} = (480.164)_{10}$

Seven-segment Display Code

Seven-segment displays(Fig. below) are very common and are found almost everywhere, from pocket calculators, digital clocks and electronic test equipment to petrol pumps. A single seven-segment display or a stack of such displays invariably meets our display requirement. There are both LED and LCD types of seven-segment display. Furthermore, there are common anode-type LED displays where the arrangement of different diodes, designated a, b, c, d, e, f and g, is as shown in Fig.below , and common cathode-type displays where the individual diodes are interconnected as shown in Fig. 5.1(b).

Each display unit usually has a dot point (DP).

The DP could be located either towards the left (as shown) or towards the right of the figure ‘8’ display pattern. This type of display can be used to display numerals from 0 to 9 and letters from A to F. Table 5.1 gives the binary code for displaying different numeric and alphabetic characters for both the common cathode and the common anode type displays. A ‘1’ lights a segment in the common cathode type display, and a ‘0’ lights a segment in the common anode type display.



a) Seven-segment displays **b)** common cathode-type **c)** common anode-type

Fig 50 Seven-segment displays.

Table 4 Seven-segment display code.

Common cathode type ‘1’ means ON									Common anode type ‘0’ means ON								
	a	b	c	d	e	f	g	DP		a	b	c	d	e	f	g	DP
0	1	1	1	1	1	1	0		0	0	0	0	0	0	0	1	
1	0	1	1	0	0	0	0		1	1	0	0	1	1	1	1	
2	1	1	0	1	1	0	1		2	0	0	1	0	0	1	0	
3	1	1	1	1	0	0	1		3	0	0	0	0	1	1	0	
4	0	1	1	0	0	1	1		4	1	0	0	1	1	0	0	
5	1	0	1	1	0	1	1		5	0	1	0	0	1	0	0	
6	0	0	1	1	1	1	1		6	1	1	0	0	0	0	0	
7	1	1	1	0	0	0	0		7	0	0	0	1	1	1	1	
8	1	1	1	1	1	1	1		8	0	0	0	0	0	0	0	
9	1	1	1	0	0	1	1		9	0	0	0	1	1	0	0	
a	1	1	1	1	1	0	1		a	0	0	0	0	0	1	0	
b	0	0	1	1	1	1	1		b	1	1	0	0	0	0	0	
c	0	0	0	1	1	0	1		c	1	1	1	0	0	1	0	
d	0	1	1	1	1	0	1		d	1	0	0	0	0	1	0	
e	1	1	0	1	1	1	1		e	0	0	1	0	0	0	0	
f	1	0	0	0	1	1	1		f	0	1	1	1	0	0	0	

Binary Logic

Binary logic deals with variables that take on two discrete values and with operations that assume logical meaning. The two values the variables take may be called by different names (e.g., true and false, high and low, asserted and not asserted, yes and no etc.), but for our purpose it is convenient to think in terms of numerical values and using the values of 1 and 0.

The variables are designated by letters of the alphabet such as A, B, C, x, y, z, etc., with each variable having two and only two distinct possible values: 1 and 0. There are three basic logical operations: AND, OR and NOT.

1. **AND**: This operation is represented by a **dot** or by the absence of an operator.
   For example x.y = z or xy = z is read “x AND y is equal to z”. The logical operation AND mean that z = 1 if and only if x = 1 if and y = 1; otherwise z = 0.

2. **OR**: This operation is represented by a **plus** sign. For example x + y = z is read “x OR y is

equal to z” meaning that z = 1, x = 1. or if y = 1 or if both x = 1 and y = 1. If both x = 0,

and y = 0, then z = 0.

2. **NOT**: This operation is represented by a prime (sometimes by a bar). For example x' = z

(or $\bar{x}$ □□z) is read “x not is equal to z” meaning that z is what x is not.

In other words, if x = 1, then z = 0; but if x = 0, then z = 1.

Binary logic should not confused with binary arithmetic. One should realize that an arithmetic variable designates a number that may consist of many digits. A logic variable is always either a 1 or 0. For example, in binary arithmetic we have 1 + 1 = 10 (read: “one plus one is equal to 2”), while in binary logic, we have 1 + 1 = 1 (read: “one OR one is equal to one”).

For each combination of the values of x and y, there is a value of z specified by the definition of the logical operation. These definitions may be listed in a compact from using ‘truth tables’. A truth table is a table of all possible combinations of the variables showing the relation between the values that the variables may take and the result of the operation. For example, the truth tables for the operations AND and OR with, variables x and y are obtained by listing all possible values that the variables may have when combined in pairs. The result of the operation for each combination is then listed in a separate row.

LOGIC GATES

The logic gate is the most basic building block of any digital system, including computers. Each one of the basic logic gates is a piece of hardware or an electronic circuit that can be used to implement some basic logic expression.

Logic gates are electronic circuits that can be used to implement the most elementary logic expressions, also known as Boolean expressions. The logic gate is the most basic building block of combinational logic. There are three basic logic gates, namely the OR gate, the AND gate and the NOT gate. Other logic gates that are derived from these basic gates are the NAND gate, the NOR gate, the EXCLUSIVEOR gate and the EXCLUSIVE-NOR gate.

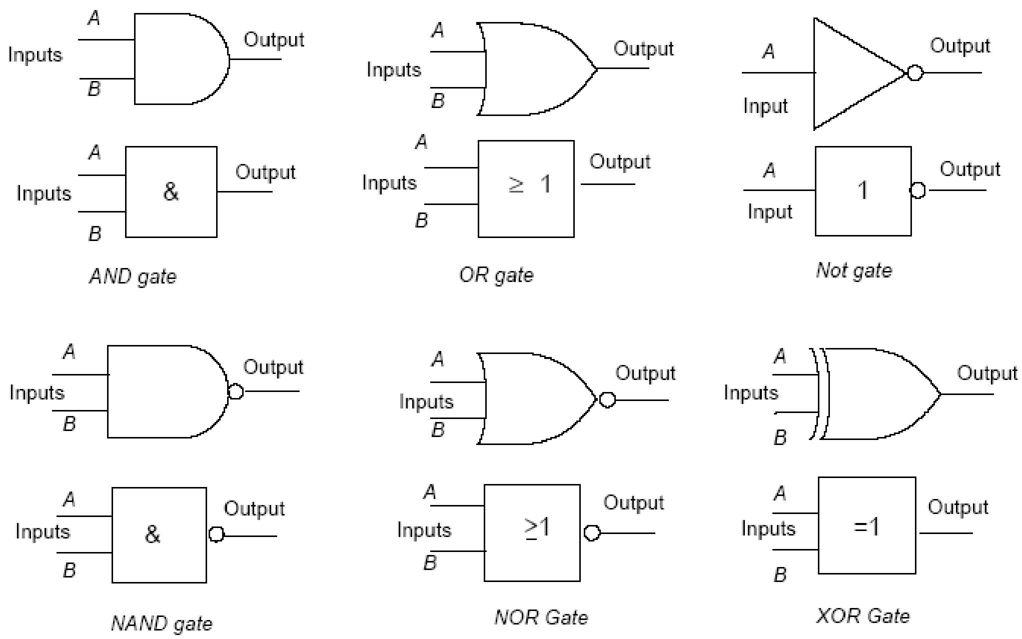


Fig51 Logic gate symbols

Truth Table

A truth table lists all possible combinations of input binary variables and the corresponding outputs of a logic system. The logic system output can be found from the logic expression, often referred to as the Boolean expression that relates the output with the inputs of that very logic system.

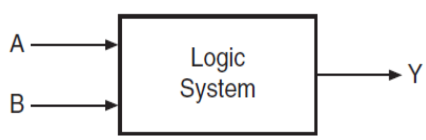


Fig 52 Two-input logic system.

When the number of input binary variables is only one, then there are only two possible inputs, i.e. ‘0’ and ‘1’. If the number of inputs is two, there can be four possible input combinations, i.e. 00, 01, 10 and 11. The following fig : shows the truth table of the two-input logic system ORing operation represented by Fig. 26.

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

Fig 53 Truth table of two-input logic system ORing operation.

The logic system of Fig. is such that Y = 0 only when both A = 0 & B = 0. For all other possible input combinations, output Y = 1.

Similarly, for three input binary variables, the number of possible input combinations becomes eight, i.e. 000, 001, 010, 011, 100, 101, 110 and 111. This statement can be generalized to say that, if a logic circuit has **n** binary inputs, its truth table will have 2^n possible input combinations, or in other words 2^n rows.

Figure 27: shows the truth table of a three-input logic circuit, and it has 8 (= 2^3) rows.

A	B	C	Y
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

Fig 53 Truth table of a three-input logic system by ANDing operation.

OR Gate

The **OR** gate gives an output with any OR all inputs. It is stated in “logical terms” like this:

A + B = Y and is read “A or B equals Y”. This means that if input A is high there will be a high output or if B is high there will be a high output OR if A and B are high there will be a high output.

L= Low (0), H= High (1)

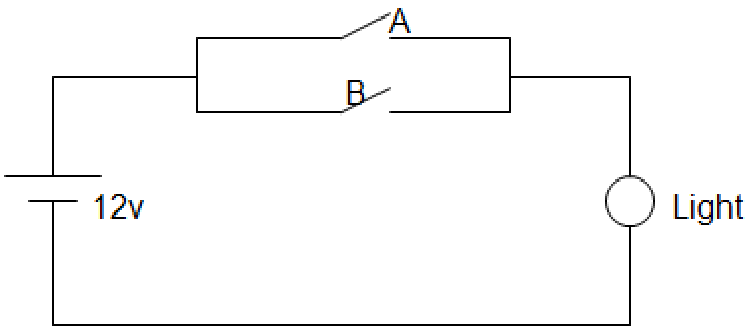


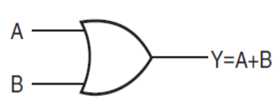
Fig54 Electrical circuit of an OR gate

Inputs		Output
A	**B**	**Y**
L	L	L
L	H	H
H	L	H
H	H	H

If "A" OR "B" is closed, the light will light. If A + B = Y(light).

An OR gate is a logic circuit with two or more inputs and one output. The output of an OR gate is LOW only when all of its inputs are LOW. For all other possible input combinations, the output is HIGH. The output of an OR gate is a logic '0' only when all of its inputs are at logic '0'. For all other possible input combinations, the output is logic '1'. Figure 7.5 shows the circuit symbol and the truth table of a two-input OR gate. The operation of a two-input OR gate is explained by the logic expression

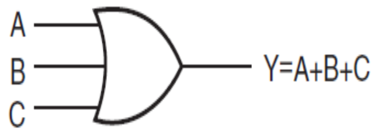
$$Y = A+B$$



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(a) (b)

Fig 55 (a) Two-input OR gate. (b) the truth table of a two-input OR gate.



A	B	C	Y
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

(a) (b)

Fig56 (a) Three-input OR gate, and (b) the truth table of a three-input OR gate.

Example 1

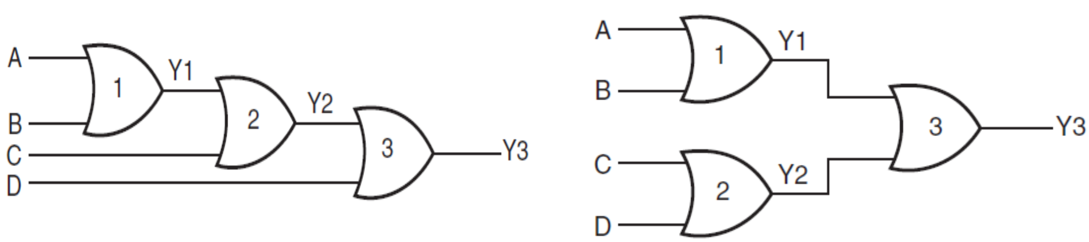
How would you hardware-implement a four-input OR gate using two-input OR gates only?

Solution

Figure 31: (a) shows one possible arrangement of two-input OR gates that simulates a four-input OR gate. A, B, C and D are logic inputs and Y_3 is the output.

Figure 31: (b) shows another possible arrangement. In the case of Fig. 31: (a), the output of OR gate 1 is Y_1 = (A+B). The second OR gate produces the output Y_2 = (Y_1+C) = (A+B+C). Similarly, the output of OR gate 3 is Y_3 = (Y_2+D) = (A+B+C+D). In the case of Fig. 31: (b), the output of OR gate 1 is Y_1 = (A+B).

The second OR gate produces the output Y_2 = (C +D). Output Y_3 of the third OR gate is given by(Y_1+Y_2) = (A+B+C +D).



(a) (b)

Figure 57: For Example 1.

AND Gate

The **AND** gate gives an output when ALL inputs are present. It is stated in "logical terms" like this: A * B = Y and is read "A and B = Y". This means that if input A is high AND input B is high the output will be high. There will be no output if just A or just B is high.

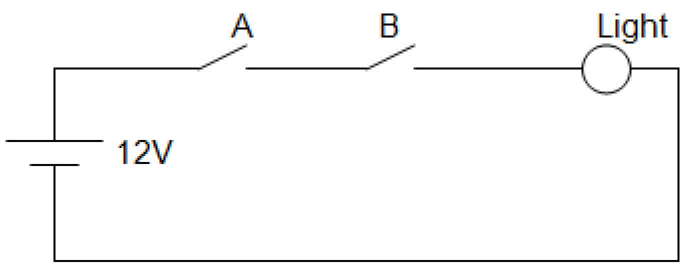


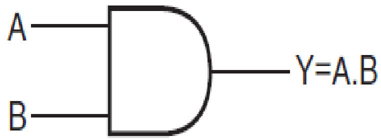
Fig 58 Electrical circuit of an AND gate

Inputs		Output
A	**B**	**Y**
L	L	L
L	H	L
H	L	L
H	H	H

If **A** AND **B** are closed, then the light will light. If A * B = Y(light).

An AND gate is a logic circuit having two or more inputs and one output. The output of an AND gate is HIGH only when all of its inputs are in the HIGH state. In all other cases, the output is LOW. When interpreted for a positive logic system, this means that the output of the AND gate is a logic '1' only when all of its inputs are in logic '1' state. In all other cases, the output is logic '0'. The logic symbol and truth table of a two-input AND gate are shown in Figs 59;(a) and (b) respectively.

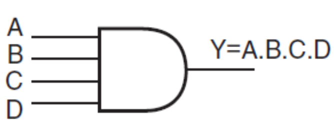
The AND operation on two independent logic variables A and B is written as Y = A.B and reads as Y equals **A** AND **B** and not as **A** multiplied by **B**. Here, **A** and **B** are input logic variables and **Y** is the output. An AND gate performs an ANDing operation:



A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1

Fig 60Two-input AND gate.

Figures 34: (a) show the logic symbols of four-input AND gates and Figure 34:(b) gives the truth table of a four-input AND gate.



A	B	C	D	Y
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	1

(a) (b)

Fig6**1** (a) logic symbols of four-input AND gate & (b) truth table of a four-input AND gate.

- for a two-input AND gate, Y = **A.B**;
- for a three-input AND gate, Y = A.B.C;
- for a four-input AND gate, Y = **A.B.C.D**.

Example 2

Show the logic arrangement for implementing a four-input AND gate using two-input AND gates only.

Solution

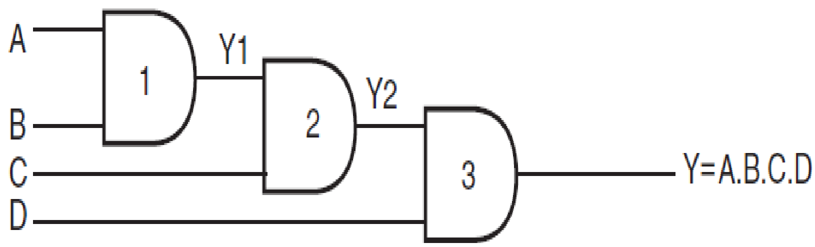
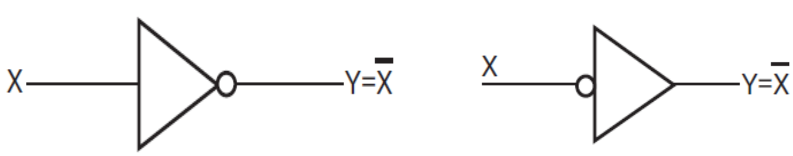


Fig 62 Implementation of a four-input AND gate using two-input AND gates.

NOT Gate

A NOT gate is a one-input, one-output logic circuit whose output is always the complement of the input. That is, a LOW input produces a HIGH output, and vice versa. When interpreted for a positive logic system, logic '0' at the input produces logic '1' at the output, and vice versa. It is also known as a 'complementing circuit' or an 'inverting circuit'. Figure 36: shows the circuit symbol and the truth table.

The NOT operation on a logic variable X is denoted as $\bar{X}$ or X'. That is, if X is the input to a NOT circuit, then its output Y is given by Y = X or X'and reads as Y equals NOT X. Thus, if X = 0,Y = 1 and if X = 1,Y = 0.

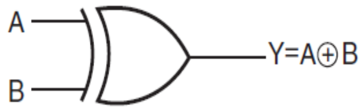


X	Y
0	1
1	0

Figure 63:Logic symbol and truth table of NOT gate

EXCLUSIVE-OR Gate

The EXCLUSIVE-OR gate, commonly written as EX-OR gate, is a two-input, one-output gate. Figures 37(a) and (b) respectively show the logic symbol and truth table of a two-input EX-OR gate. As can be seen from the truth table, the output of an EX-OR gate is a logic '1' when the inputs are **unlike** and a logic '0' when the inputs are like.



A	B	Y
0	0	0
0	1	1
1	0	1
1	1	0

Fig 64(a) Circuit symbol of a two-input EXCLUSIVE-OR gate, (b) the truth table of a two input EXCLUSIVE-OR gate

Introduction to PLCs

A PLC (Programmable Logic Controllers) is an industrial computer used to monitor inputs, and depending upon their state make decisions based on its program or logic, to control (turn on/off) its outputs to automate a machine or a process.

A programmable logic controller (PLC), also referred to as a **programmable** controller, is the name given to a type of computer commonly used in commercial and Industrial control applications. PLCs differ from office computers in the type's tasks that they of perform and the hardware and software they require to perform these tasks.

While the specific applications vary widely all PLCs monitor inputs and other variable values make decisions based on a stored program and control outputs to automate a process or machine..

Both the PC and its associated peripherals are designed so that they can be easily integrated into an industrial control system and easily used in all their intended functions

NEMA defines a programmable logic controller as:

"A digitally operating electronic apparatus which uses a programmable memory for the internal storage of instructions by implementing specific functions such as logic sequencing, timing, counting, and arithmetic to control, through digital or analog input/output modules, various types of machines or processes".

PLC

- PLC is the abbreviation for Programmable Logic Controller.
- Most widely used industrial process control technology
- Industrial grade computer
- PLCs are real time systems
- PLCs have eliminated most of the hardwiring (relays / contactors)
- A PLC has three main aspects: the inputs, outputs and the control program.
    - The inputs are connected to sensors, pushbutton, switch, etc that inform the PLC about the environment.
    - The program uses a set of logical instructions that drives the outputs based on the inputs.
    - The outputs are connected to the devices that need to be controlled.

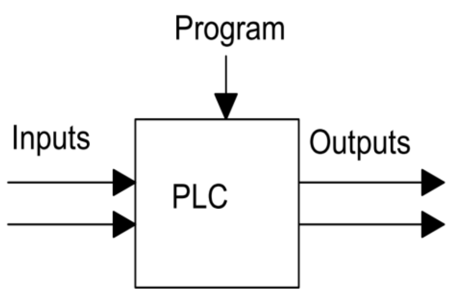


Fig 63 *A programmable logic controller*

. PLC Origin:

- Developed to replace relays in the late 1960s
- Costs dropped and became popular by 1980s
- Now used in many industrial designs

Historical Background

- The Hydromantic Division of the General Motors Corporation specified the design criteria for the first programmable controller in 1968

Their primary goal: To eliminate the high costs associated with inflexible, relay-controlled systems.

Programmable Controller Development

1968 ↑ Programmable concept developed

1969 ↑ Hardware CPU controller, with logic instructions, 1 K of memory and 128 I/O points

1974 ↑ Use of several (multi) processors within a PLC - timers and counters; arithmetic operations; 12 K of memory and 1024 I/O points

1976 ↑ Remote input/output systems introduced

1977 ↑ Microprocessors - based PLC introduced

1980 ↑ Intelligent I/O modules developed Enhanced communications facilities Enhanced software features (e.g. documentation) Use of personal microcomputers as programming aids

1983 ↑ Low - cost small PLC's introduced

1985 on ↑ Networking of all levels of PLC, computer and machine using SCADA software

Leading Brands of PLC

AMERICAN

1. Allen Bradley
2. Gould Medico
3. Texas Instruments

4. General Electric

5. Westinghouse

6. Cutter Hammer

7. Square D

EUROPEAN 1. Siemens

2. Klockner & Mouller

3. Festo

4. Telemechanique

JAPANESE 1. Toshiba

2. Omron

3. Fanuc

4. Mitsubishi

PLC Size

SMALL **-** it covers units with up to 128 I/O's and memories up to 2 Kbytes.

– these PLC's are capable of providing simple to advance levels or machine controls.

MEDIUM **-** have up to 2048 I/O's and memories up to 32 Kbytes.

L ARGE **-** the most sophisticated units of the PLC family. They have up to 8192 I/O's and memories up to 750 Kbytes.

– can control individual production processes or entire plant

Basic PLC Operations

PLC :

- Monitors inputs
- Makes decisions based on it’s program
- Controls outputs to automate a process

Table 5 Comparison between Hardwired and Programmable Control Systems

Comparison	
Hardwired Control Systems	**Programmable Control Systems**
• The functions are determined by the **physical wiring**	• The functions are determined by a **program** stored in the memory
• Changing the functions means **changing the wiring**	• The **control functions** can be changed simply by changing the program
• Can be contact-making type (relay, contactors) or electronic type (logic circuit)	• Consist of a control device, to which all the sensors and actuators are connected

- **In a traditional industrial control system (Hardwired Control Systems)**, all control devices are wired directly to each other according to how the system is supposed to operate.
- **In a PLC system** instead of being wired directly to each other, all equipment is wired to the PLC.

Advantages of using PLC’s

- Highly reliable
- Highly versatile (universal applicability)
- Simple troubleshooting

- Simple installation
- Quick modification of the program (highly flexible)
- Capable of task not possible with relays before as indicated by the following:
    - calculation
    - information exchange
    - text and graphic display
    - data processing
    - networking
- Low space requirement
- Low power consumption
- High processing speed
- No moving parts, hence no wearing parts

Disadvantages of using PLC's

- High initial cost (for a simple process)
- Sensitive to dust, high temperature and high humidity
- Repair must be made by a qualified personnel
- Not very widespread
- No uniform programming language

Traditional PLC Applications

In automated system, PLC controller is usually the central part of a process control system.

To run more complex processes it is possible to connect more PLC controllers to a central computer.

PLC Hardware

Hardware Components of a PLC System

Processor unit (CPU), Memory, Input/Output, Power supply unit, Programming device, and other devices.

COMPONENTS OF PLC

A PLC basically consists of two elements

The central processing unit (CPU)

- is the part of a programmable controller that retrieves, decodes, stores, and processes information.
- is the "brains" of a programmable controller

The CPU has three parts:

- the processor
- the memory system
- the power supply

The input/output system

- is the section of a PLC to which all of the field devices are connected.
- If the CPU can be thought of as the brains of a PLC, then the I/O system can be thought of as the arms and legs.
- The I/O system consists of two main parts:
  - the rack
  - I/O modules

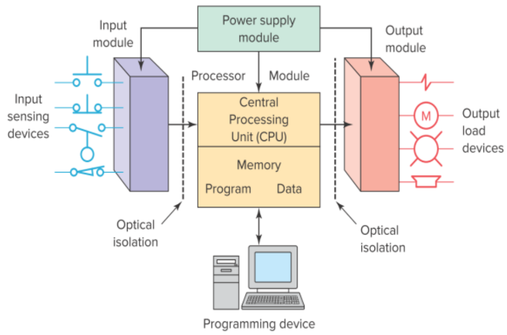


Fig67 Components of PLC system

Field devices

All of the field devices connected to a PLC can be classified in one of two categories:

- **Inputs:** are devices that supply a signal/data to a PLC

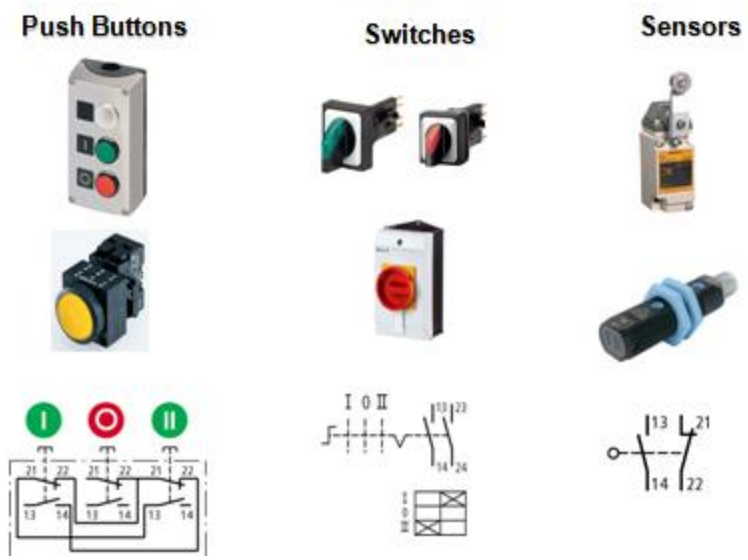


Figure 13: Input Devices for PLC control systems

- **Outputs:** are devices that await a signal/data from the PLC to perform their control functions
  - » Lights,
  - » horns,
  - » motors, and
  - » valves

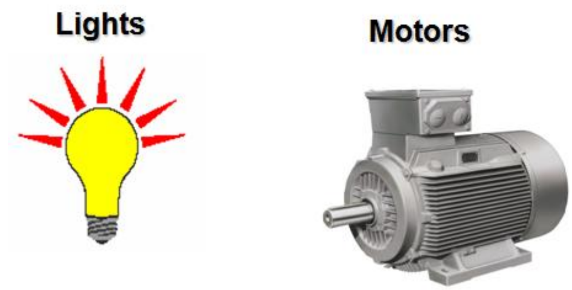


Fig:67 output Devices

Fig: 68 versus Conventional Technology

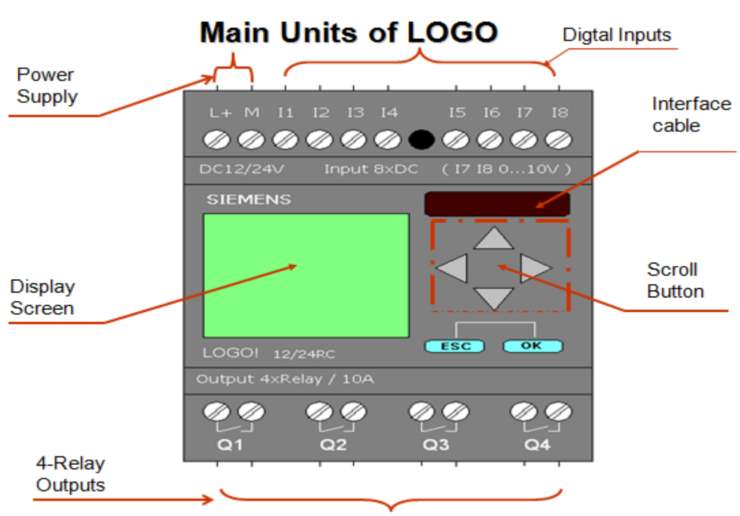


Fig 69 Units of LOGO PLC

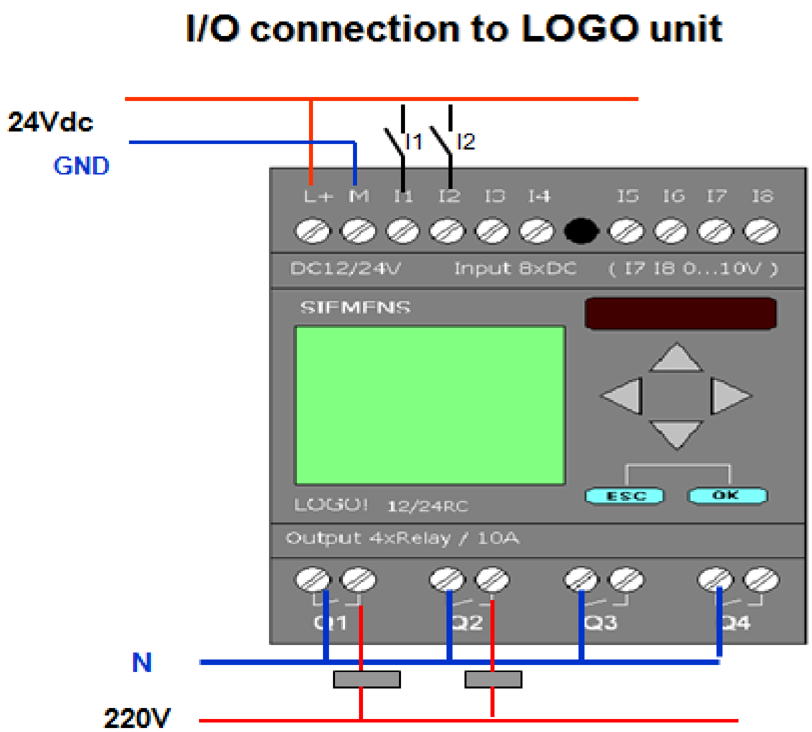


Fig 70 I/O connection to LOGO unit

System Busses

The internal paths along which the digital signals flow within the PLC are called busses.

The system has four busses:

The CPU uses the data bus for sending data between the different elements,

The address bus to send the addresses of locations for accessing stored data,

The control bus for signals relating to internal control actions,

The system bus is used for communications between the I/O ports and the I/O unit.

PLC Operation

Input Relays

These are connected to the outside world. They physically exist and receive signals from switches, sensors, etc. Typically they are not relays but rather they are transistors.

Internal Utility Relays

These do not receive signals from the outside world nor do they physically exist. They are simulated relays and are what enables a PLC to eliminate external relays. There are also some special relays that are dedicated to performing only one task.

Counters

These do not physically exist. They are simulated counters and they can be programmed to count pulses. Typically these counters can count up, down or both up and down. Since they are simulated they are limited in their counting speed. Some manufacturers also include highspeed counters that are hardware based.

PLC Communications

Extension modules

PLC I/O number can be increased through certain additional modules by system extension through extension lines. Each module can contain extension both of input and output lines.

Extension modules can have inputs and outputs of a different nature from those on the PLC controller. When there are many I/O located considerable distances away from the PLC an economic solution is to use I/O modules and use cables to connect these, over the long distances, to the PLC.

Remote I/O connections

When there are many I/O located considerable distances away from the PLC an economic solution is to use I/O modules and use cables to connect these, over the long distances, to the PLC.

Input Module: Functions

The input module of a PLC is the module to which sensors are connected to. The sensor signals are to be passed on to the central control unit. The important functions of an input module are as follows:

- Reliable signal detection
- Voltage adjustment of control voltage to logic voltage
- Protection of sensitive electronics from external voltages
- Screening of signals

Output Module: Functions

Output modules conduct the signals of the central control unit to final control elements, which are actuated according to the task. The functions of the output module, as seen from the application of the PLC, include the following:

- Voltage adjustment of logic voltage to control voltage
- Protection of sensitive electronics from spurious voltages
- Power amplification sufficient for the actuation of major final control elements
- Short circuit and overload protection of output

Application of PLCs

Examples of industries where PLC's are used for control and automation purpose:

- ✓ Tire industries
- ✓ Food Processing plants
- ✓ Bulk material handling system at ports
- ✓ Ship un-loader & wagon loaders
- ✓ Steel plants & Blast furnace charging
- ✓ Galvanizing plant
- ✓ Dairy automation
- ✓ Pulp factory & printing industry

Examples of service area: where PLC's are used for control and automation purpose:

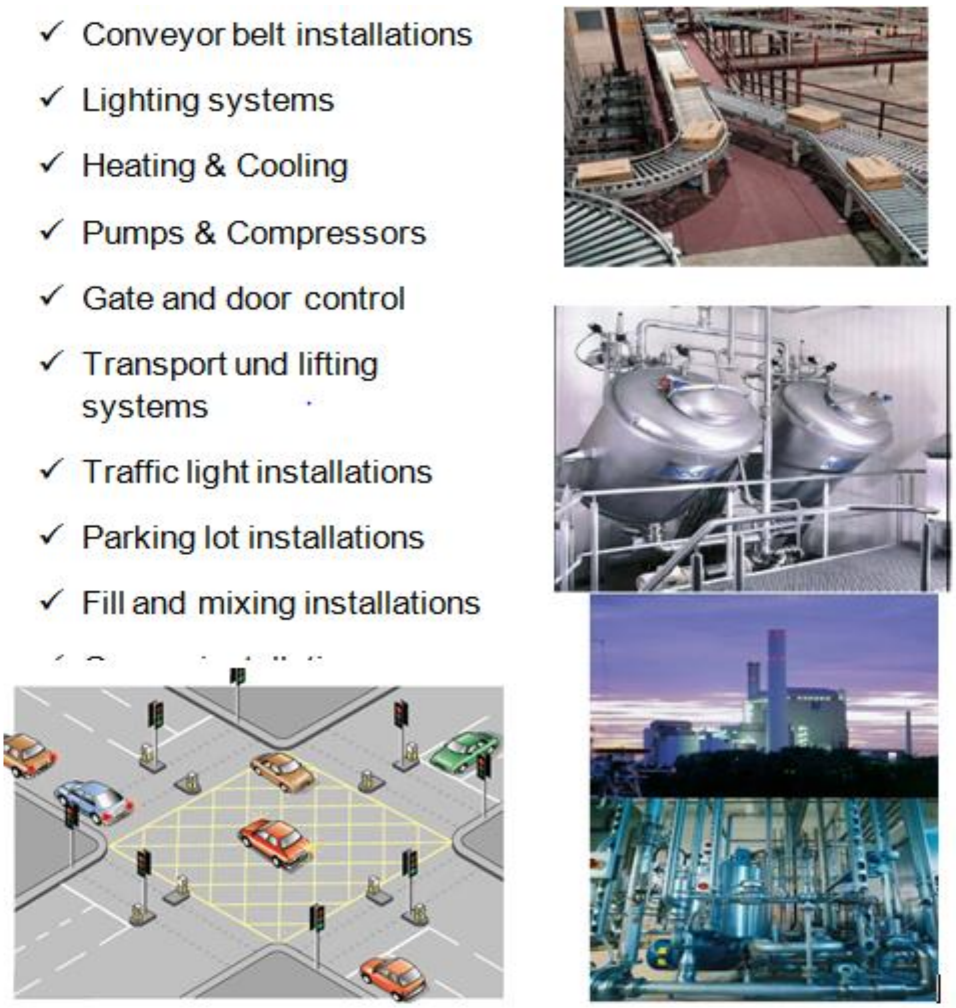


Fig71 Examples of PLC's service area for control and automation purpose:

A. Input/output Module

The I/O interface section of a PLC connects it to external field devices.

The main purpose of the I/O interface is to condition the various signals received from or sent to the external input and output devices.

Input modules convert signals from discrete or analog input devices to logic levels acceptable to PLC's processor.

Output modules converts signal from the processor to levels capable of driving the connected discrete or analog output devices.

The voltage and current signals generated by the sensors, transducers, limit switches, pushbuttons etc are applied to the terminals of the input module. The input module helps in the following ways:

- It converts the field signal into a standard control signal for processing by PLC. The standard control signal delivered by input module could be 5V or 9V whereas the field signal received by it, could be 24V DC, 230V AC or 115V AC.
- If required, it isolates the field signal from the CPU.
- It sends one input at a time to CPU by multiplexing action.
- Depending upon the nature of input signal coming from the field the input module could be:
    - ✓ Analog input module
    - ✓ Digital input module

The typical analog current input modules are 4 to +- 20mA, 0 to +- 50 mA and analog voltage input modules are 0 to +- 50mV, 0 to +- 500mV and 0 to +- 10 V.

The typical digital input modules are 24V DC, 115V AC and 230V AC.

The output module acts as a link between the CPU and the output devices located in the field. The field devices could be relays, contactors, lamps, motorized potentiometers, actuators, solenoid valves, control valves dampers etc. these devices actually control the process.

The output module converts the output signal delivered by CPU into an appropriate voltage level suitable for the output field device. The voltage signal provided by CPU could be 5V or 9V, but the output module converts this voltage level into say 24V DC, or 115V AC or 230V AC etc.

Thus the output module on receiving signal from the processor switches voltage to the respective output terminals. This makes the actuators (i.e. contactors, relays etc.) or indicating lights etc. connected to the terminal to become ON or OFF.

Like input module, an output module could be an analog or digital.

The selection is based on the voltage rating of the field output devices. If the output device is analog then analog output module is required and if it is digital like contactor coil or a lamp then digital output module is required.

Typical analog output modules have the ratings of 4mA to +-20 mA or 0 to +-10V and the digital output modules have 24V DC, 115V AC and 230V AC output.

Input/output Circuits

Different Types of I/O Circuits

1. Pilot Duty Outputs:- Outputs of this type typically are used to drive high-current electromagnetic loads such as solenoids, relays, valves, and motor starters. These loads are highly inductive and exhibit a large inrush current. Pilot duty outputs should be capable of withstanding an inrush current of 10 times the rated load for a short period of time without failure.

2. General - Purpose Outputs: - These are usually low- voltage and low-current and are used to drive indicating lights and other non-inductive loads. Noise suppression may or may not be included on these types of modules.

3. Discrete Inputs: - Circuits of this type are used to sense the status of limit switches, push buttons, and other discrete sensors. Noise suppression is of great importance in preventing false indication of inputs turning on or off because of noise.

4. Analog I/O:- Circuits of this type sense or drive analog signals. Analog inputs come from devices, such as thermocouples, strain gages, or pressure sensors, that provide a signal voltage or current that is derived from the process variable.

Standard Analog Input signals: 4-20mA; 0-10V. Analog outputs can be used to drive devices such as voltmeters, X-Y recorders, servomotor drives, and valves through the use of transducers.

Standard Analog Output signals: 4-20mA; 0-5V; 0-10V.

5. Special - Purpose I/O :- Circuits of this type are used to interface PLCs to very specific types of circuits such as servomotors, stepping motors PID (proportional plus integral plus derivative) loops, high-speed pulse counting, resolver and decoder inputs, multiplexed displays, and keyboards. This module allows for limited access to timer and counter presets and other PLC variables without requiring a program.

Memory:- The most important characteristic of a programmable controller is the user's ability to change the control program quickly and easily. The PLC's architecture makes this programmability feature possible

- The **memory system is the** area in the PLC's CPU where all of the sequences of instructions, or programs, are stored and executed by the processor to provide the desired control of field devices.
- The memory sections that contain the control programs can be changed, or reprogrammed, to adapt to manufacturing line procedure changes or new system start-up requirements.

The memory system in the processor module has two parts:

  - a system memory and
  - a

    n application memory

- System memory includes an area called the EXECUTIVE, composed of permanently-stored programs that direct all system activities, such as execution of the users control program, communication with peripheral devices, and other system activities. The system memory also contains the routines that implement the PLC’s instruction set, which is composed of specific control functions such as logic, sequencing, timing, counting, and arithmetic. System memory is generally built from read-only memory devices.

- The application memory is divided into the data table area and user program area. The data table stores any data associated with the user’s control program, such as system input and output status data, and any stored constants, variables, or preset values. The data table is where data is monitored, manipulated, and changed for control purposes. The user program area is where the programmed instructions entered by the user are stored as an application control program.

Arithmetic Logic Unit (ALU)

- ALU is the “organizer” of the PLC.
- The following operations are carried out by ALU.
  - ✓ It organizes the input of external signals and data.
  - ✓ It performs logic operation with the data.
  - ✓ It performs calculation
  - ✓ It takes account of the value of internal timers and counters
  - ✓ It takes account of the signal states stored in the flags.
  - ✓ It stores the signal states of the input in the “process input image” (internal memory of CPU) before each program scanning cycle.
  - ✓ It stores the result of the logic operation in the “process output image” (internal memory of CPU) during the program scan.
  - ✓ It organizes the output of the result.

B. Bus system :

A bus system Is a path for the transmission of signals. In the programmable controllers, it is responsible for the signal exchange between processor and input/output modules. The bus comprises of several signal lines i.e. wires/tracks. There are three buses in PLC:

1. **Address bus** which enables the selection of a memory location or a module.
2. **Data bus** which carries the data from modules to processor and vice versa.
3. **Control bus** which transfers control and timing signals for the synchronization of the CPU's activities within the programmable controller.

C. Power supply

The power supply module generates the voltages required for the electronics modules of the PLC from the main supply.

PLC Communications

Serial Communications

- PLC communications facilities normally provides serial transmission of information.

Common Standards: **RS 232** and **Local Area Network (LAN)**

RS 232

- Used in short-distance computer communications, with the majority of computer hardware and peripherals.
- Has a maximum effective distance of approx. 30 m.

Local Area Network (LAN)

- Local Area Network provides a physical link between all devices plus providing overall data exchange management or protocol, ensuring that each device can "talk" to other machines and understand data received from them.

- LANs provide the common, high-speed data communications bus which interconnects any or all devices within the local area.
- LANs are commonly used in business applications to allow several users to share costly software packages and peripheral equipment such as printers and hard disk storage

Pneumatic Systems

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

PNEUMA - greek root term means “breath”

Pneumatic systems use air pressure to create mechanical motion. As shown in Figure 48, the basic system includes an intake filter that traps dirt before it enters the system, an air compressor that provides a source of compressed air, a dryer that removes the moisture in the air, a pressure tank that is a reservoir of compressed air, a pressure regulator that maintains air pressure, a valve that controls the air flow, and a pneumatic cylinder that creates the mechanical motion.

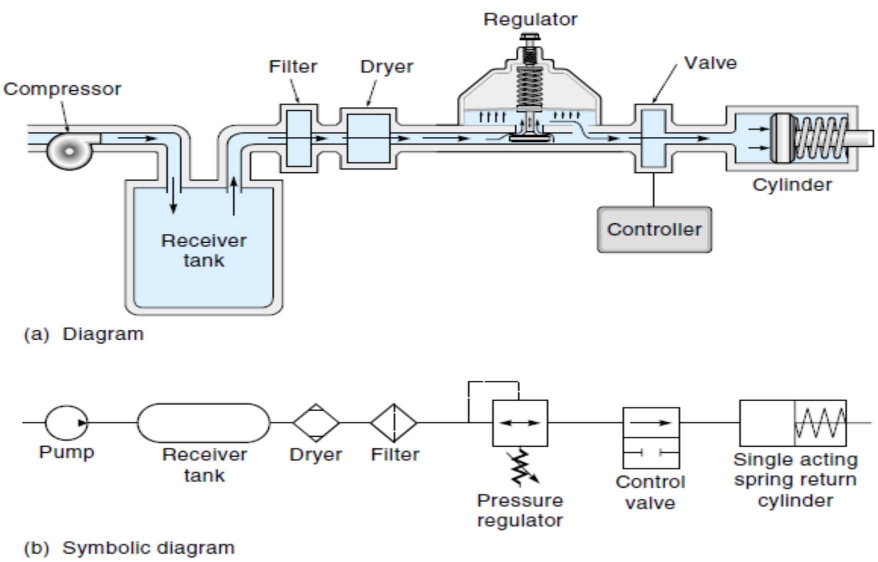


Fig 72 A basic pneumatic system (simplified).

The consumption of compressed air

Examples of components that consume compressed air include execution components (cylinders), directional control valves and assistant valves.

Execution component

Pneumatic execution components provide rectilinear or rotary movement. Examples of pneumatic execution components include cylinder pistons, pneumatic motors, etc. Rectilinear motion is produced by cylinder pistons, while pneumatic motors provide continuous rotations.

There are many kinds of cylinders, such as single acting cylinders and double acting cylinders.

SEVEN BASIC ELECTRICALDEVICES

Seven basic electrical devices commonly used in the control of fluid power systems are

1. Manually actuated push button switches
2. Limit switches
3. Pressure switches

4. Solenoids
5. Relays
6. Timers
7. Temperature switches

Other devices used in electro pneumatics are

1. Proximity sensors
2. Electric counters

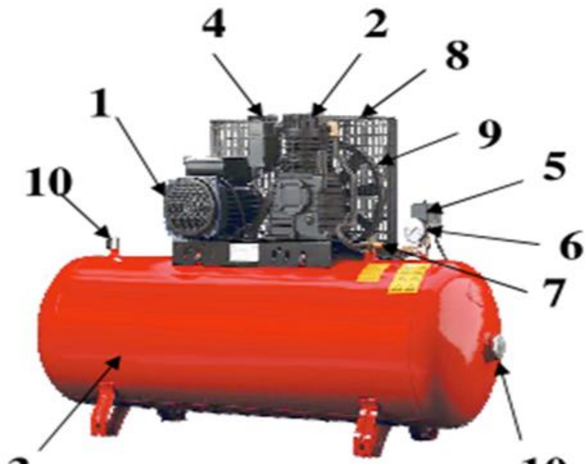


Fig 1.

1. Electric Motor
2. Compressor
3. Reservoir
4. Air Intake Filter
5. Pressure Control Switch
6. Reservoir Pressure Gauge
7. Pressure Release Valve
8. Safety Guard
9. Belt Drive System
10. Air Takeoff Point

Fig parts of compressor

Single acting cylinder

A single acting cylinder has only one entrance that allows compressed air to flow through. Therefore, it can only produce thrust in one direction (Fig.). The piston rod is propelled in the opposite direction by an internal spring, or by the external force provided by mechanical movement or weight of a load (Fig.).

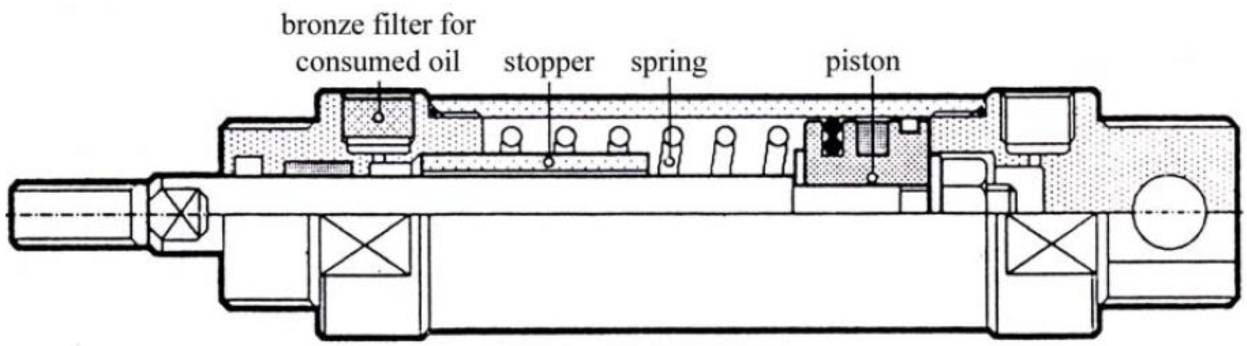


Fig. 73 Cross section of a single acting cylinder

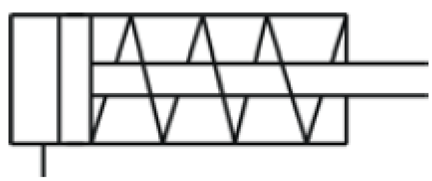


Fig74. Pneumatic symbol of a single acting cylinder

Double acting cylinder

In a double acting cylinder, air pressure is applied alternately to the relative surface of the piston, producing a propelling force and a retracting force (Fig. 51). As the effective area of the piston is small, the thrust produced during retraction is relatively weak. The impeccable tubes of double acting cylinders are usually made of steel. The working surfaces are also polished and coated with chromium to reduce friction.

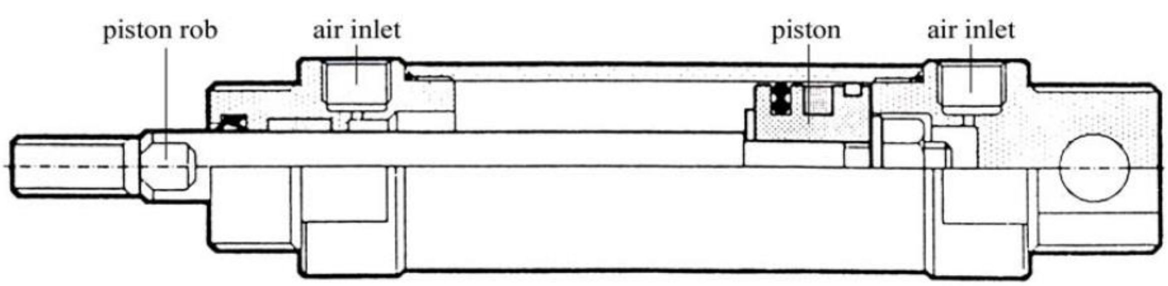


Fig. 75Cross section of a double acting cylinder

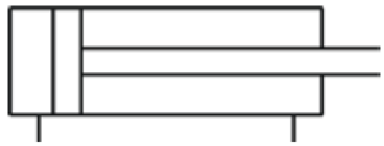


Fig.76 Pneumatic symbol of a double acting cylinder

Directional control valve

Directional control valves ensure the flow of air between air ports by opening, closing and switching their internal connections. Their classification is determined by the number of ports, the number of switching positions, the normal position of the valve and its method of operation.

Common types of directional control valves include **2/2, 3/2, 5/2**, etc. The first number represents the number of ports; the second number represents the number of positions. A directional control valve that has two ports and five positions can be represented by the drawing in Fig. 53, as well as its own unique pneumatic symbol.

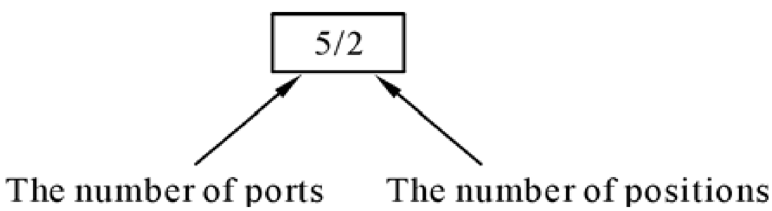


Fig.77 Describing a 5/2 directional control valve

Types of Directional control valves are:

(i) 2/2 Directional control valve

(ii) 3/2 Directional control valve

(iii) 5/2 Directional control valve

Control valve

A control valve is a valve that controls the flow of air. Examples include non-return valves, flow control valves, shuttle valves, etc.

(i) Non-return valve

(ii) Flow control valve

(iii) Shuttle valve

Main pneumatic components

Pneumatic components can be divided into two categories:

1. Components that produce and transport compressed air.
2. Components that consume compressed air.

All main pneumatic components can be represented by simple pneumatic symbols. Each symbol shows only the function of the component it represents, but not its structure. Pneumatic symbols can be combined to form pneumatic diagrams. A pneumatic diagram describes the relations between each pneumatic component, that is, the design of the system.

Pneumatic Valves.

The pneumatic valve is one of the most important components in the circuit or system. They are grouped according to their function, signal type and construction. Valves are sub-divided into the following:

1. Directional control valves
2. Flow control valves
3. Non-return valves
4. Pressure control valves
5. Combinational valves
6. Solenoid valves

As valve types are too many and varied we will be focusing on the 3/2 Valve and the 5/2 directional control valves. So that we might understand how valves are specified and described we have firstly to look at their symbolic representation.

Additional system components

A number of additional pieces of equipment are required to treat the compressed air to maintain pressure and quality before it is put to use. These include

- Filters, coolers
- Separators

- Dryers
- Flow controllers
- Lubricators and
- Traps and drains.

i) . Separators

They remove contamination from the Air (dirt, water, oils, etc.) before it enters the Compressor. They may be installed after every intercooler to remove condensed moisture. Lubricant injected rotary compressors have a separator immediately after the compressor to remove the injected oil before it is cooled and re-circulated for a second compression stage.

ii) Filters

These include particle filters to remove solids, coalescing filters to remove lubricant and moisture and absorbent filters to remove very fine particles

iii) Flow controllers

They regulate the pressure and deliver varying volumes of air in response to the changing demands on the system.

iv) Traps and Drains

Mechanical and Electrical traps are used to allow for the removal of the contaminants but not the compressed air. Mechanical types use a float type device and the electrical traps use a timed solenoid type or a liquid level sensing device to do the same job.

v) Lubricators

Compressor lubricants are designed to cool, seal and lubricate moving parts. Lubricators may also be installed on air lines close to the point of use for pneumatic tool such as drills, grinders, Chisels, etc.

Symbols

Now it is a time to study electro pneumatic symbols used in electro pneumatic circuitry. This symbols standard for fluid power symbols is based on ISO 1219-1. This is a set of basic shapes and rules for the construction of fluid power symbols. Cylinders can be drawn to show their extreme or intermediate positions of stroke and any length above their width. Valves show all states in the one symbol. The prevailing state is shown with the port connections.

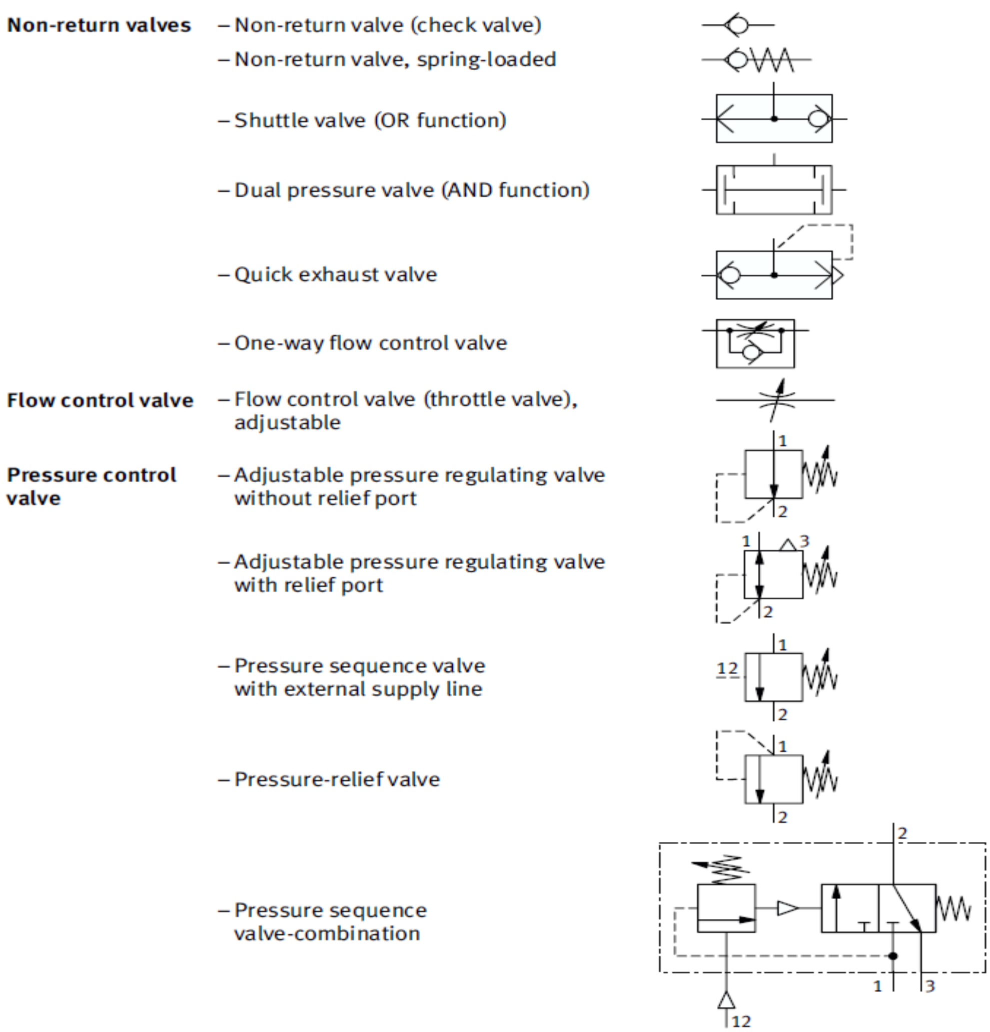


Fig 78Pneumatic component symbols

The directional control valve is represented by the number of controlled connections, the number of positions and the flow path. In order to avoid faulty connections, all the inputs and outputs of a valve are identified.

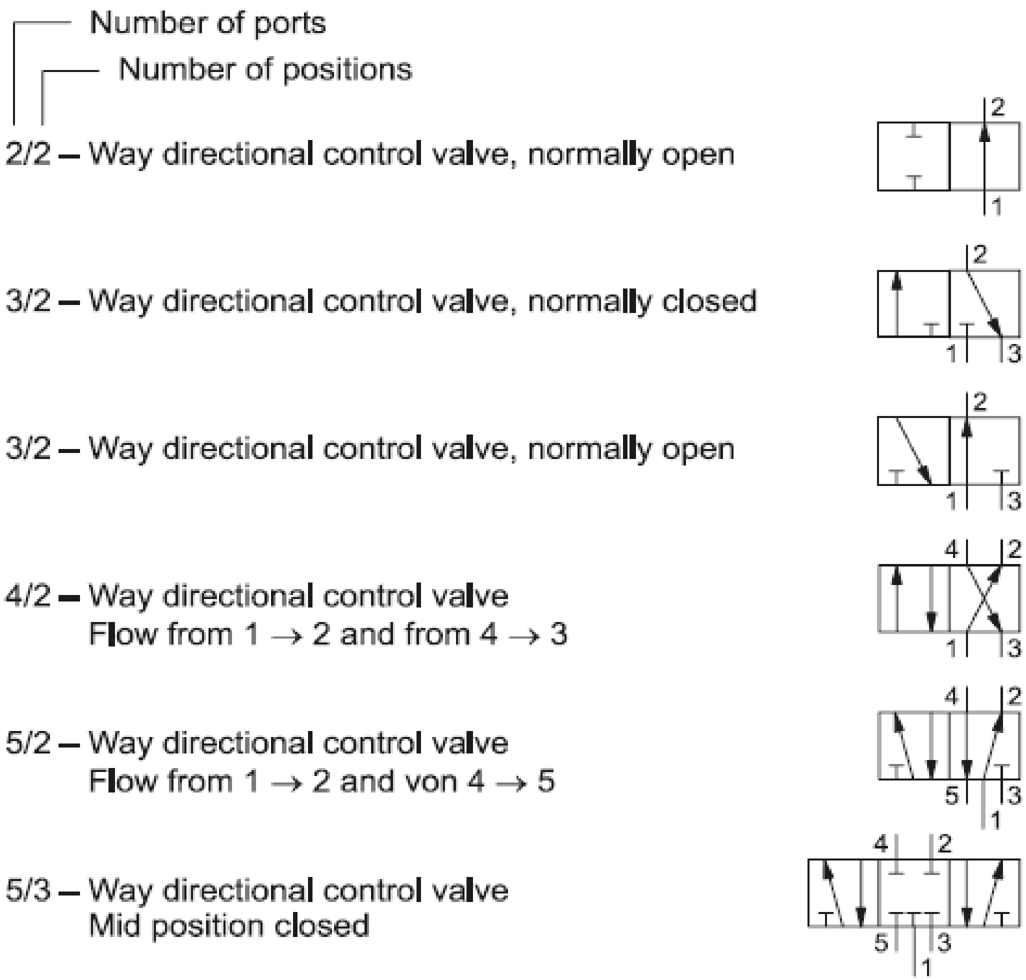


Fig: 79Pneumatic valves symbols

Principles of pneumatic control

Pneumatic circuit

Pneumatic control systems can be designed in the form of pneumatic circuits. A pneumatic circuit is formed by various pneumatic components, such as cylinders, directional control valves, flow control valves, etc. Pneumatic circuits have the following functions:

1. To control the injection and release of compressed air in the cylinders.

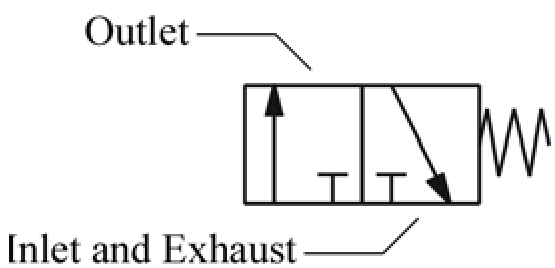
2. To use one valve to control another valve.

Pneumatic circuit diagram

A pneumatic circuit diagram uses pneumatic symbols to describe its design. Some basic rules must be followed when drawing pneumatic diagrams.

Basic rules to Pneumatic circuit diagram

1. A pneumatic circuit diagram represents the circuit in static form and assumes there is no supply of pressure. The placement of the pneumatic components on the circuit also follows this assumption.
2. The pneumatic symbol of a directional control valve is formed by one or more drawn on the top. Each function of the valve (the position of the valve) shall be represented by a square. If there are two or more functions, the squares should be arranged horizontally (Fig.).



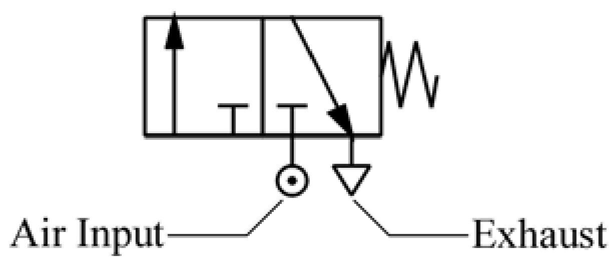


Fig. : 80 3/2 directional control valve **Fig : 813/2 directional control valve**

(Normally Closed type) **(Normally Cosed type)**

3. Arrows **"↓↖"** are used to indicate the flow direction of air current. If the external port is not connected to the internal parts, the symbol **"┬"** is used. The symbol **"⊙"** underneath the square represents the air input, while the symbol **"∇"** represents the exhaust. Fig. 157 shows an example of a typical pneumatic valve.
4. The pneumatic symbols of operational components should be drawn on the outside of the squares. They can be divided into two classes: mechanical and manual (Fig. 58 and 59).

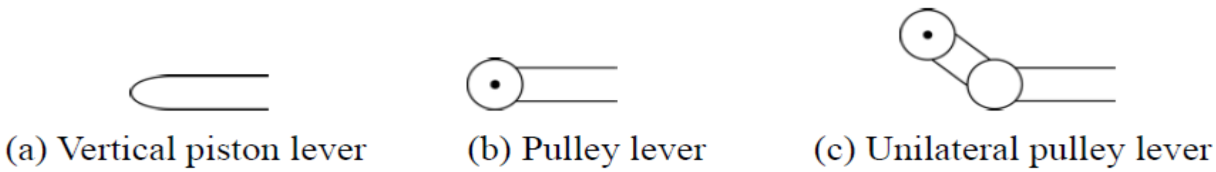


Fig. 82: Mechanically operated pneumatic components

Fig. 83: Manually operated pneumatic components

5. Pneumatic operation signal pressure lines should be drawn on one side of the squares, while
   triangles are used to represent the direction of air flow (Fig. 60).

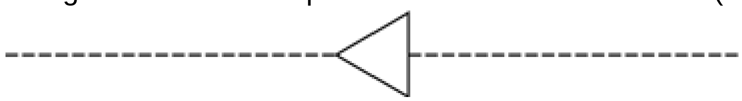


Fig. 84Pneumatic operation signal pressure line

(i) Basic principles

Fig. : shows some of the basic principles of drawing pneumatic circuit diagrams, the numbers in the diagram correspond to the following points:

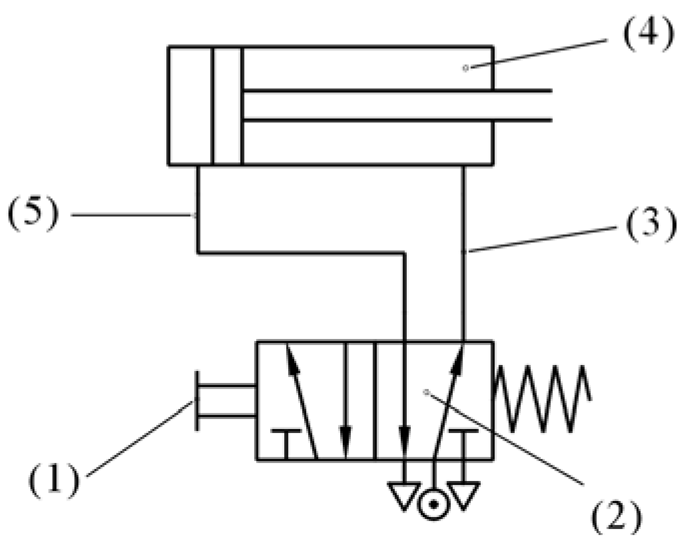


Fig.85 Basic principles of drawing pneumatic circuit diagrams

1. When the manual switch is not operated, the spring will restore the valve to its original position.
2. From the position of the spring, one can deduce that the block is operating. The other block will not operate until the switch is pushed.
3. .Air pressure exists along this line because it is connected to the source of compressed air.
4. . As this cylinder cavity and piston rod are under the influence of pressure, the piston rod is in its restored position.
5. The rear cylinder cavity and this line are connected to the exhaust, where air is released.

(ii) The setting of circuit diagrams

When drawing a complete circuit diagram, one should place the pneumatic components on different levels and positions, so the relations between the components can be expressed clearly.

This is called the setting of circuit diagrams. A circuit diagram is usually divided into three levels: power level, logic level and signal input level (Fig. 62).

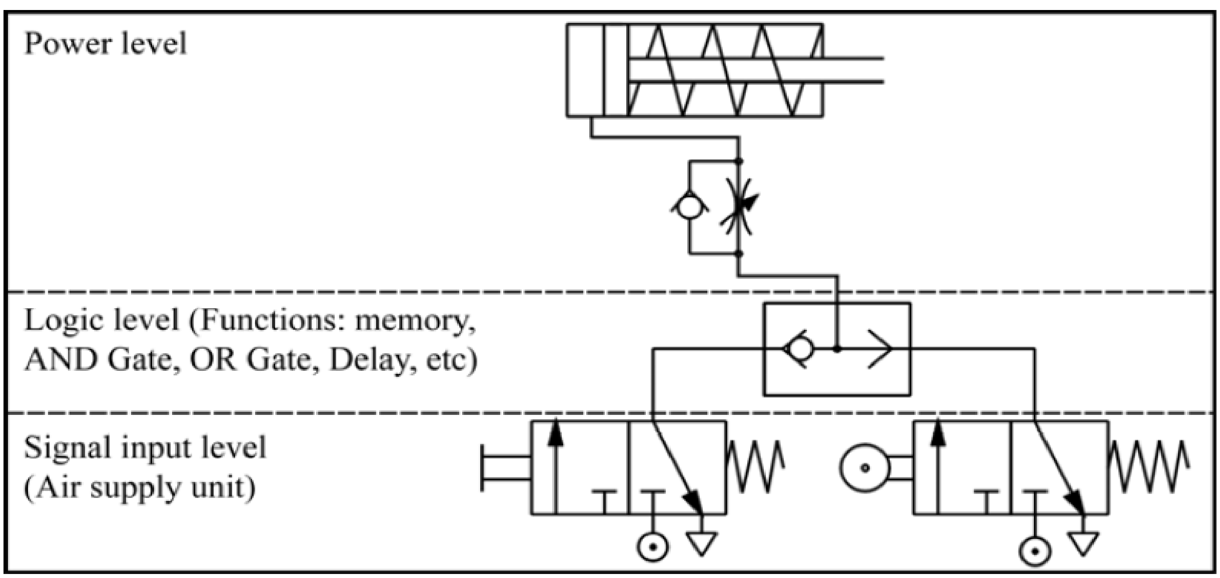


Fig.86 Power level, logic level and signal input level

Seven basic electrical devices

Seven basic electrical devices commonly used in the control of fluid power systems are

1. Manually actuated push button switches
2. Limit switches
3. Pressure switches
4. .Solenoids
5. Relays
6. Timers
7. Temperature switches

Other devices used in electro pneumatics are

1. Proximity sensors
2. Electric counters

Limit switches

Any switch that is actuated due to the position of a fluid power component (usually a piston rod or hydraulic motor shaft or the position of load is termed as limit switch. The actuation of a limit switch provides an electrical signal that causes an appropriate system response.

Limit switches perform the same function as push button switches. Push buttons are manually actuated whereas limit switches are mechanically actuated.

Control of double acting cylinder with time delay (Double solenoid)

When manual pushbutton PB1 is pressed, relay K1 changes state and the normally open contact k1 of relay is connected to solenoid coil Y1. When the normally open contact closes, the solenoid valve changes state, the cylinder travels to its final forward position where it actuates limit switch S2. This limit switch stats the time lag relay K2 (with energizing delay) . After 5 seconds the normally open contact of time lag relay energizes the solenoid coil Y2 of the directional control valve. The valve changes over and causes the piston to travel to its final rear position.

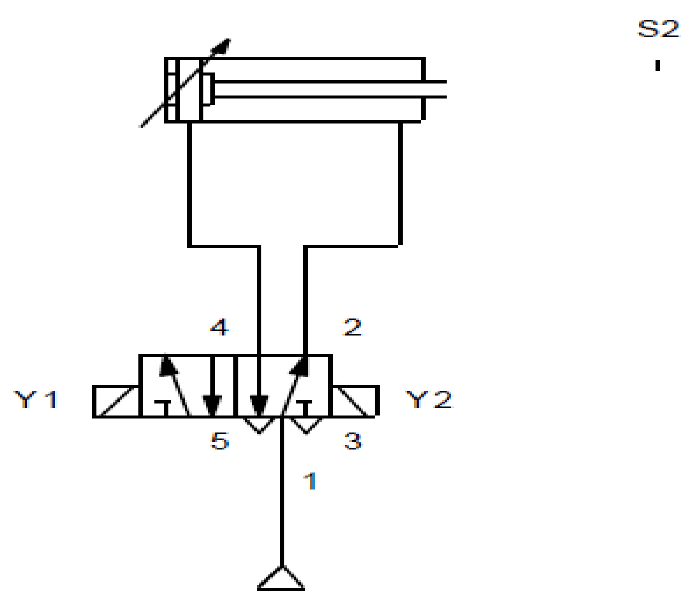


Fig 89 The pneumatic circuit, the power

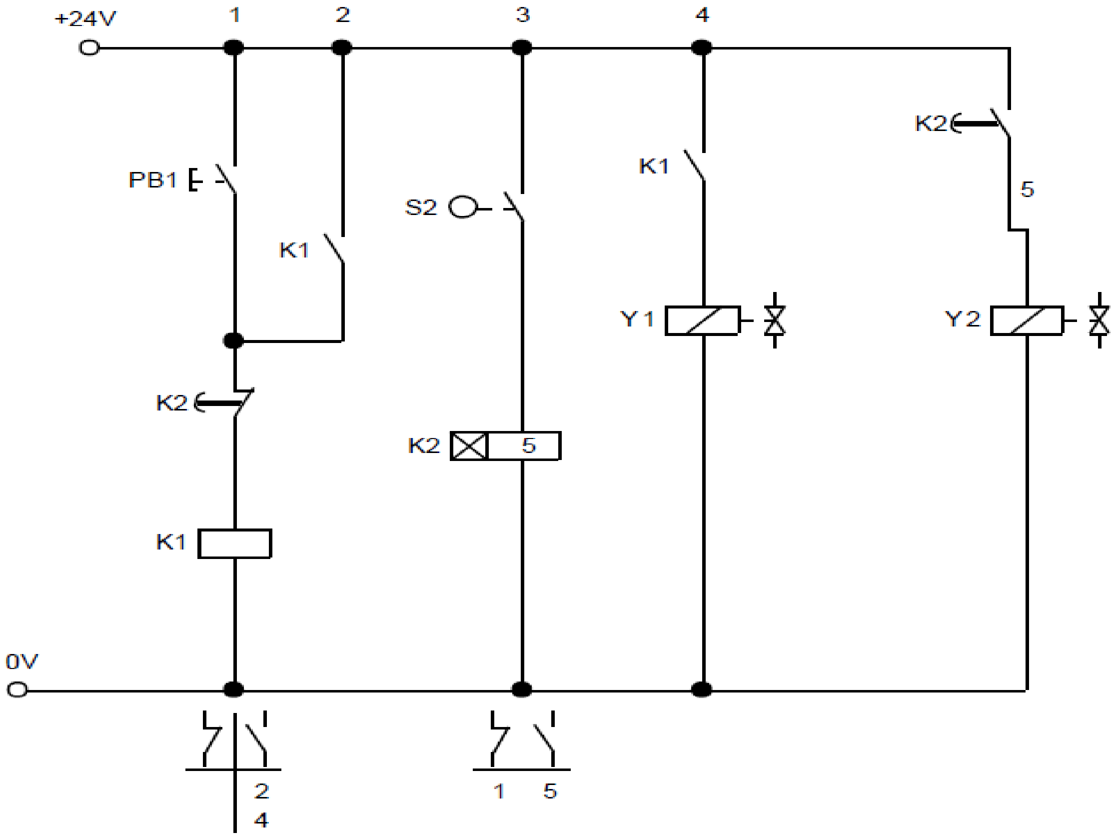


Fig 90 The electric circuit, the signal control and processing

Simple solenoid controlled circuit

The diagram shows the electrical control side and the operational side of the circuit firstly in its initial state.

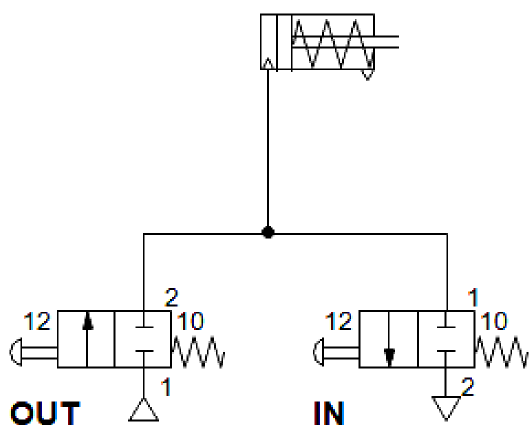
This is the simplest solenoid arrangement possible as all that is involved is a single acting actuator a 3/2 solenoid directional valve and an air supply. If the switch is activated then it brings in the solenoid coil and operates the valve. The compressed air now flows in port 1 through the valve and out port 2 operating the actuator. When the switch is released the circuit to the solenoid is broken and the 3/2 valve returns to its initial position under spring pressure.

A pneumatic system can be controlled either manually or automatically. In manual control systems, operation is sequenced by operator who decides which action to take. In automatic control systems, operation is sequenced by controller that automatically decides each action to be taken. Automatic control can be accomplished by means of:

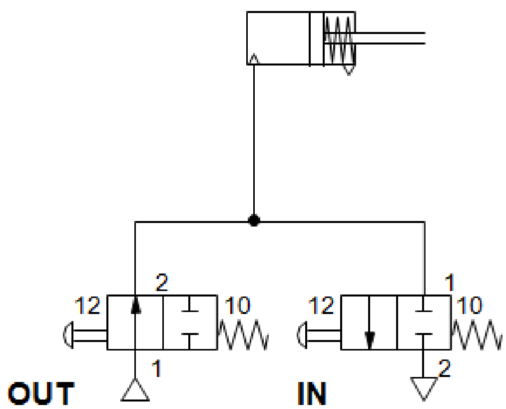
- Electrical signals
- Pneumatic signals

Actuator control 2/2 valve

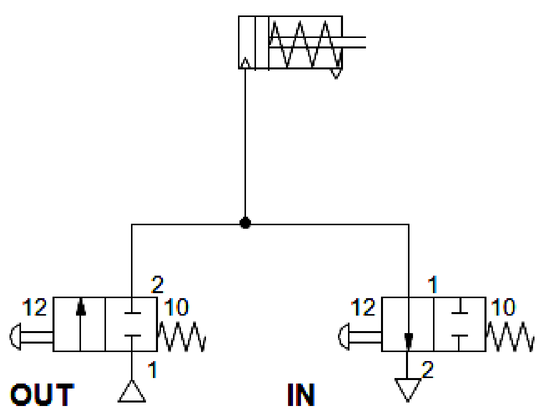
- A pair of the most basic of all valve types the 2/2 can be used to control a single acting cylinder
- The normally closed position of the valve is produced by the spring
- The operated position is produced by the push button
- One valve admits air the other valve exhausts it



- The button marked OUT is pushed to operate the valve
- Air is connected to the cylinder and it outstrokes
- Air cannot escape to atmosphere through the valve marked IN as this is closed
- The air at atmospheric pressure in the front of the cylinder vents through the breather port

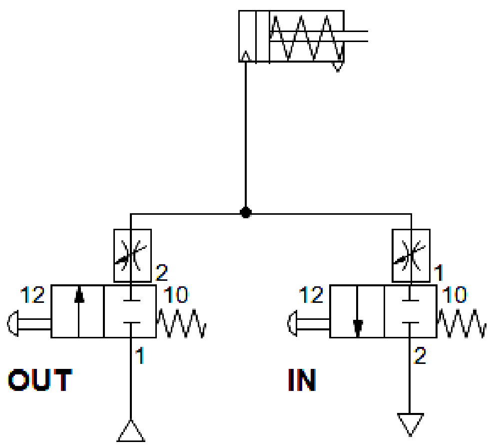


- The push button of the valve marked OUT is released and it returns to a normal closed position
- Air is now trapped in the system and provided there are no leaks the piston rod will stay in the outstroke position
- If the load increases beyond the force exerted by the air the piston rod will start to move in
    - The button marked IN is pushed to operate the valve
    - Air escapes and the piston rod moves to the in stroked position
    - The push button must be held operated until the piston rod is fully in
    - Atmospheric air will be drawn in to the front of the cylinder through the vent port



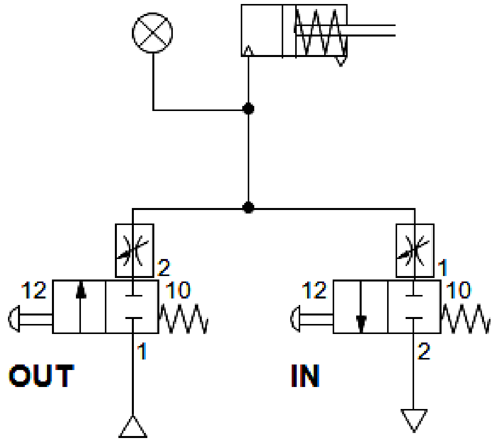
2/2 valve with Speed control

- To control the speed of the piston rod, flow restrictors are placed in the pipes close to each of the valves.
- Adjustment of the restrictors will slow down the flow rate thereby giving independent outstroke and instroke speed control



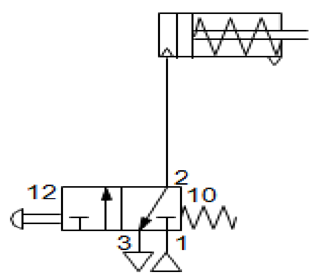
2/2 valve with Speed control & indicator or gauge

- With any compressed air system that intentionally traps air, the potential hazard of this must be recognised
- Unintended release or application of pressure can give rise to unexpected movement of the piston rod
- A pressure indicator or gauge must be fitted to warn of the presence of pressure



Actuator control 3/2 valve

- A 3 port valve provides the inlet and exhaust path and is the normal choice for the control of a single acting cylinder
- In the normal position produced by the spring, the valve is closed
- In the operated position produced by the push button the valve is open
- The push button must be held down for as long as the cylinder is outstroked



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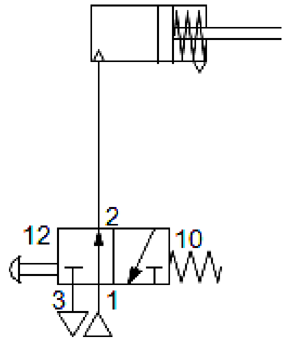
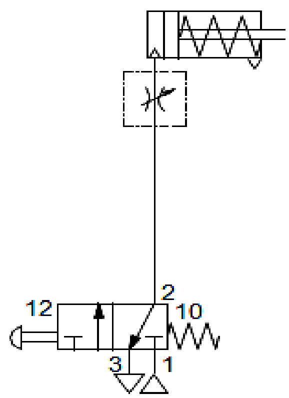
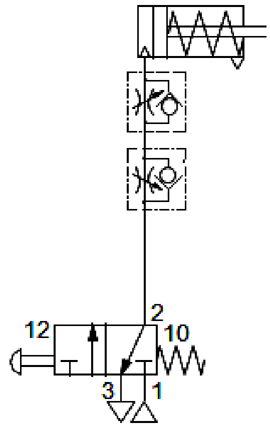


Actuator control 3/2 valve with flow regulator

- To generally slow the cylinder speed an adjustable bi-directional flow regulator or fixed restrictor can be used
- The flow regulator setting will be a compromise as the ideal outstroke speed may not produce the desired results for the in stroke speed

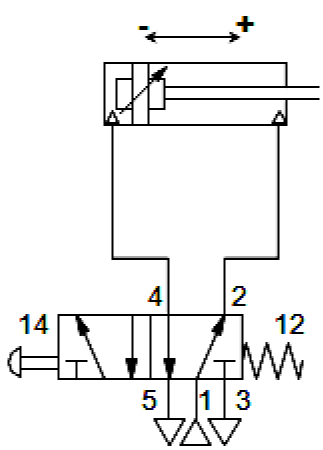


- For independent speed control in each direction two flow regulators are required
- Installed in opposite directions to each other
- Upper regulator controls the outstroke speed
- Lower regulator controls the in stroking speed



Actuator control 5/2 valve

- For a double acting cylinder the power and exhaust paths are switched simultaneously
- When the button is pushed the supply at port 1 is connected to port 4 and the outlet port 2 connected to exhaust port 3. The cylinder moves plus
- When the button is released port 1 is connected to port 2 and port 4 connected to port 5. Cylinder minus



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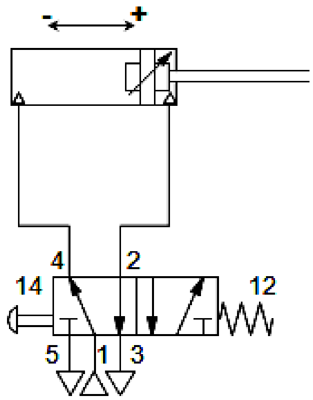
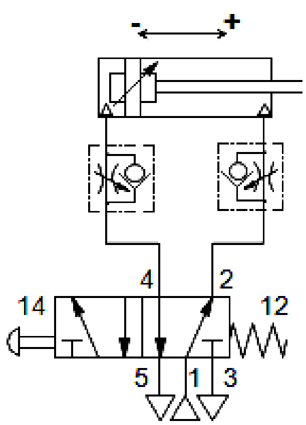
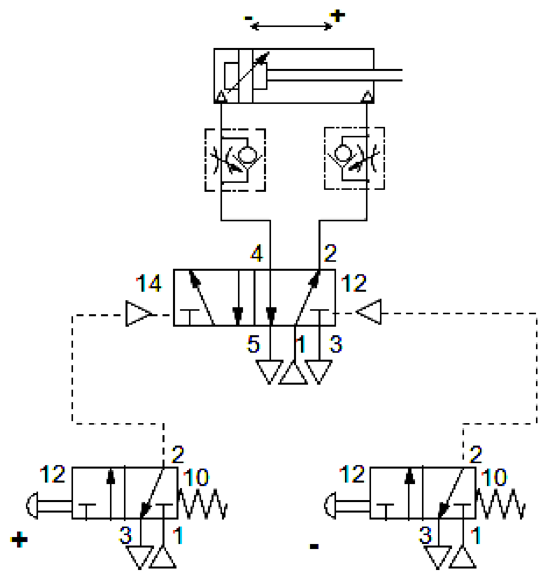


Actuator control 5/2 valve with Independent speed control

- Independent speed control of the plus and minus movements
- In most applications speed is controlled by restricting air out of a cylinder
- Full power is developed to drive the piston with speed controlled by restricting the back pressure



- Remote manual control of a double acting cylinder
- Valve marked + will cause the cylinder to outstroke or move plus
- Valve marked - will cause the cylinder to instroke or move minus
- The 5/2 double pilot valve is bi-stable therefore the push button valves only need to be pulsed



- Remote manual control of a double acting cylinder
- Valve marked + will cause the cylinder to outstroke or move plus
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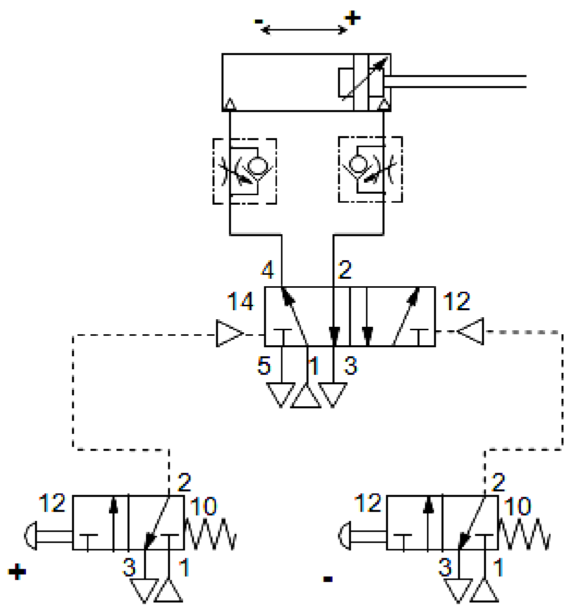

Actuator control 5/2 valve Manual control

- Remote manual control of a double acting cylinder
- Valve marked + will cause the cylinder to outstroke or move plus
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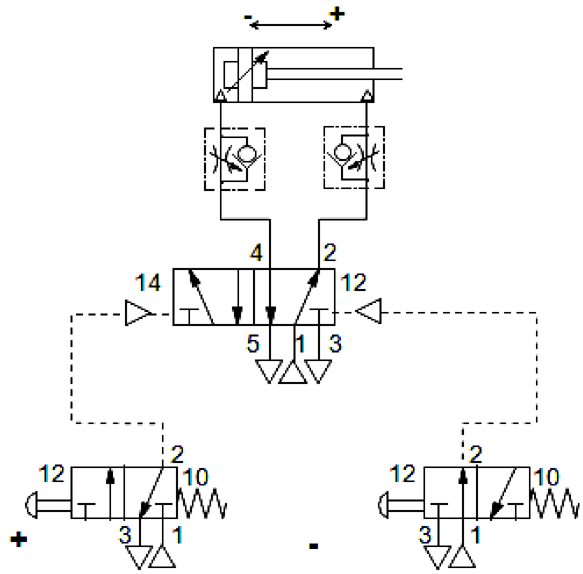
- The 5/2 double pilot valve is bi-stable therefore the push button valves only need to be pulsed



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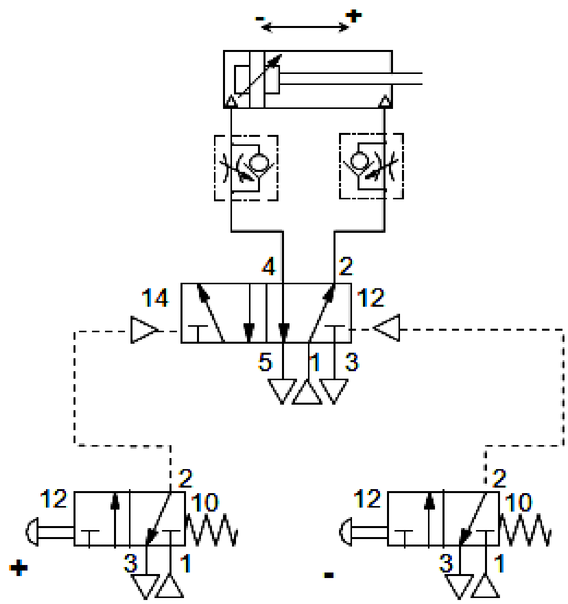
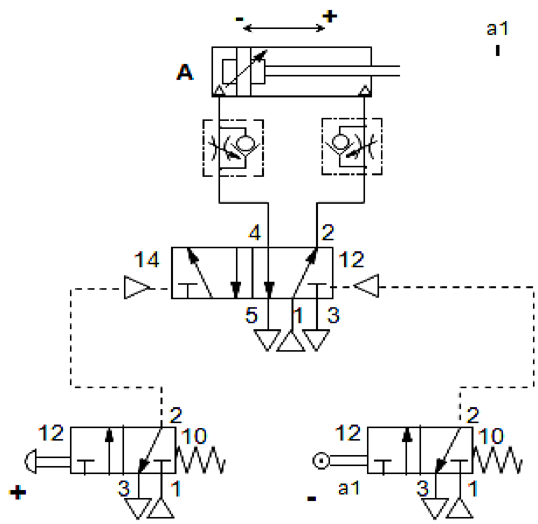


Semi-automatic control

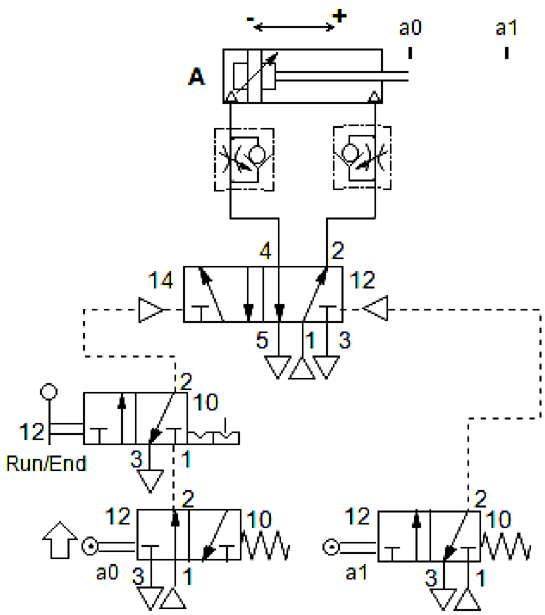
- Manual remote start of a double acting cylinder with automatic return
- Cylinder identified as “A”
- Trip valve operated at the completion of the plus stroke identified as “a1”



Fully-automatic control

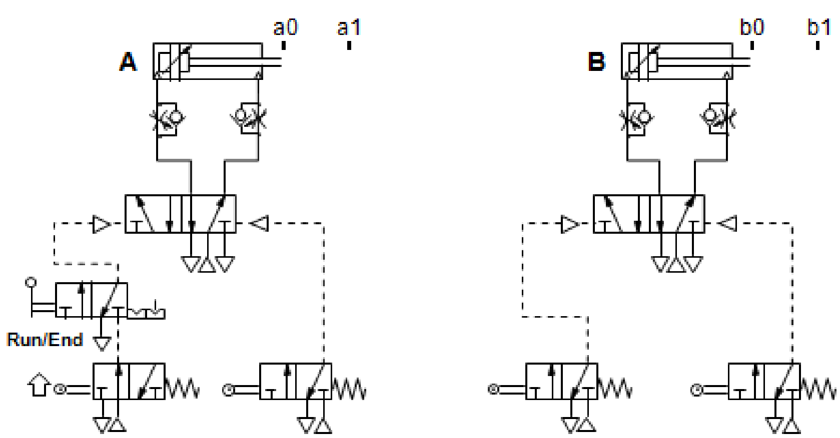
- Continuous automatic cycling from roller operated trip valves

- Manual Run and End of the automatic cycling
- Cylinder will come to rest in the instroked position regardless of when the valve is put to End
- Tags for the roller feedback valves a0 and a1 show their relative positions



Sequential control

Circuit building blocks

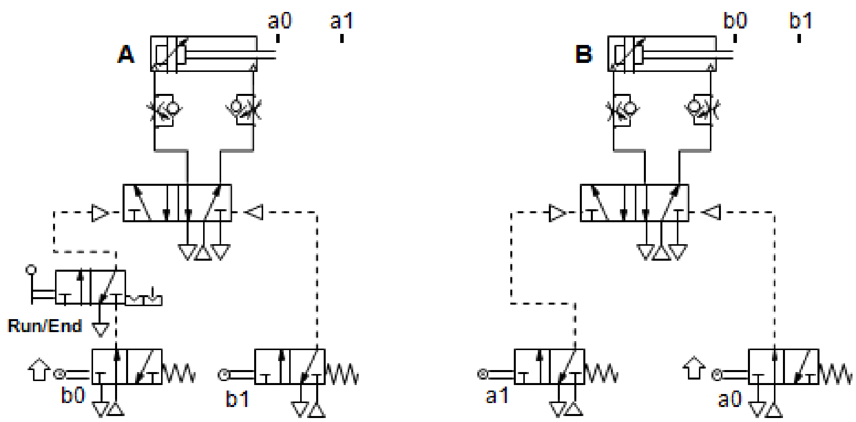


- These circuits can be considered as building blocks for larger sequential circuits consisting of two or more cylinders

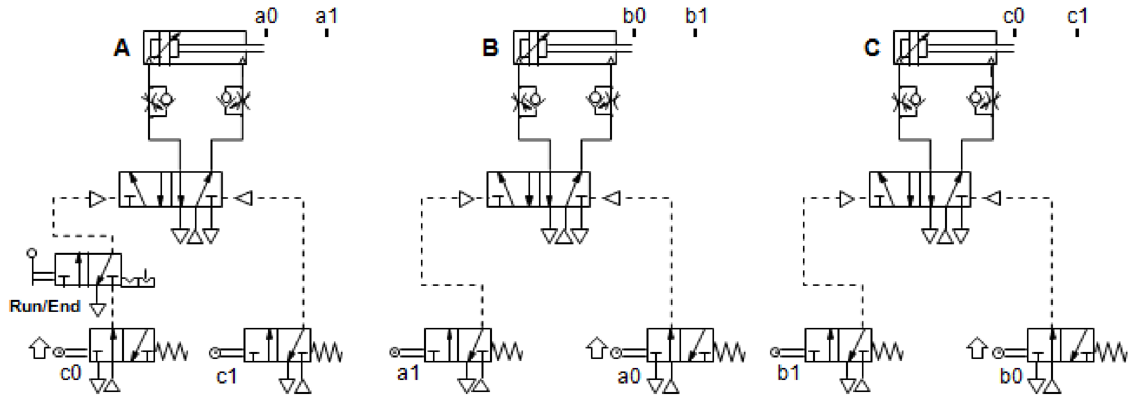
- Each actuator will have a power valve and two associated feedback valves. The first actuator to move also has a Run/End valve

Repeat pattern sequence

- A repeat pattern sequence is one where the order of the movements in the first half of the sequence is repeated in the second half
- Each actuator may have one Out and In stroke only in the sequence
- There may be any number of actuators in the sequence
- The signal starting the first movement must pass through the Run/End valve
- Needs only the basic building blocks to solve
- Examples of repeat pattern sequences:
- A+ B+ C+ D+ A- B- C- D-
- A- B+ C- A+ B- C+
- C+ A+ B- C- A- B+

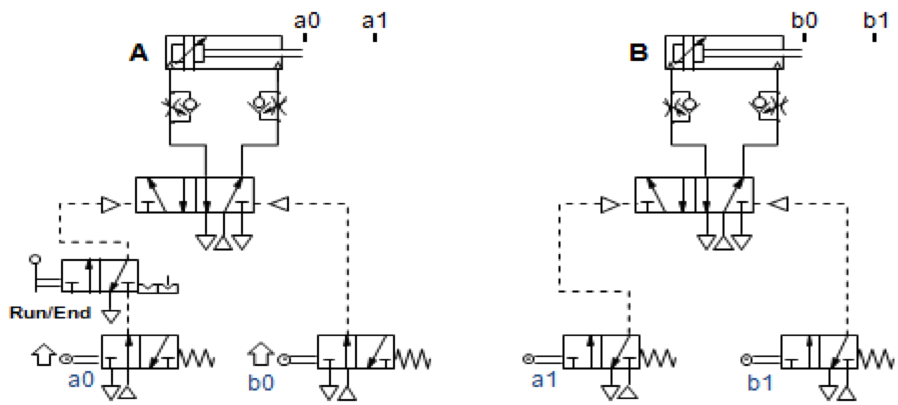


- The two cylinders A and B are to perform a simple repeat pattern sequence as follows: A+ B+ A- B-
- Apply the rule "The signal given by the completion of each movement will initiate the next movement"
- In this way the roller valves can be identified and labelled



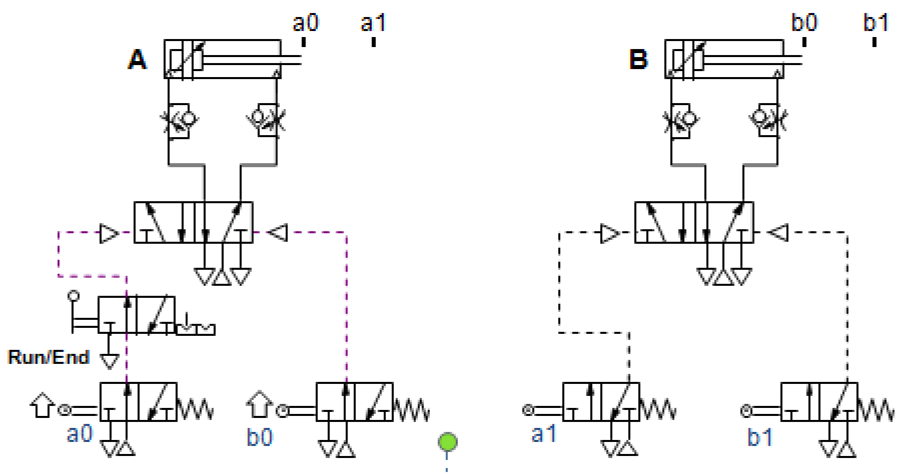
- For three cylinders A, B and C also to perform a simple repeat pattern sequence as follows: A+ B+ C+ A- B- C-
- Apply the rule "The signal given by the completion of each movement will initiate the next movement"

<u>Non-repeat pattern sequence</u>



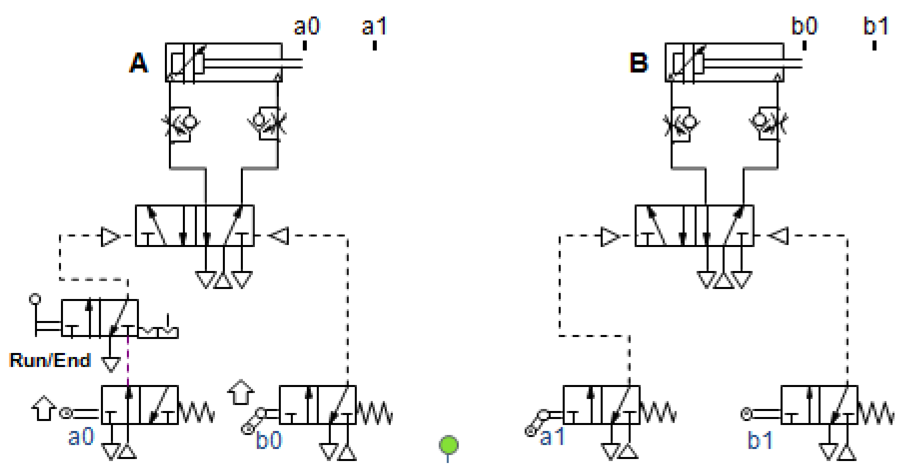
- If the rule applied to a repeat pattern sequence is applied to any other sequence there will be opposed signals on one or more of the 5/2 valves preventing operation
- This circuit demonstrates the problem
- The sequence is A+ B+ B- A-

Opposed signals



- When the valve is set to Run, cylinder A will not move because the 5/2 valve has an opposed signal, it is still being signalled to hold position by the feedback valve b0
- If A was able to move + a similar problem will occur for the 5/2 valve of B once it was +
- The sequence is A+ B+ B- A-

Mechanical solution



- The problem was caused by valves b0 and a1 being operated at the time the new opposing instruction is given
- If these two valves were "one way trip" types and over tripped at the last movement of stroke, only a pulse would be obtained instead of a continuous signal

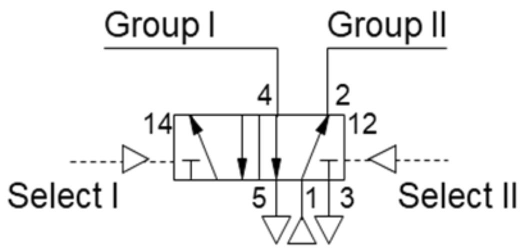
Sequence solution methods

- The main solutions to solving sequences are:
  - Cascade (pneumatic)
  - Shift register (pneumatic)
  - Electro-pneumatic
  - PLC (Programmable logic controller)
- Cascade circuits provide a standard method of solving any sequence. It uses a minimum of additional logic hardware (one logic valve per group of sequential steps)
- Shift register circuits are similar to cascade but use one logic valve for every step
- Electro-pneumatic circuits use solenoid valves and electro-mechanical relays
- PLC. The standard solution for medium to complex sequential systems (except where electrical equipment cannot be used)

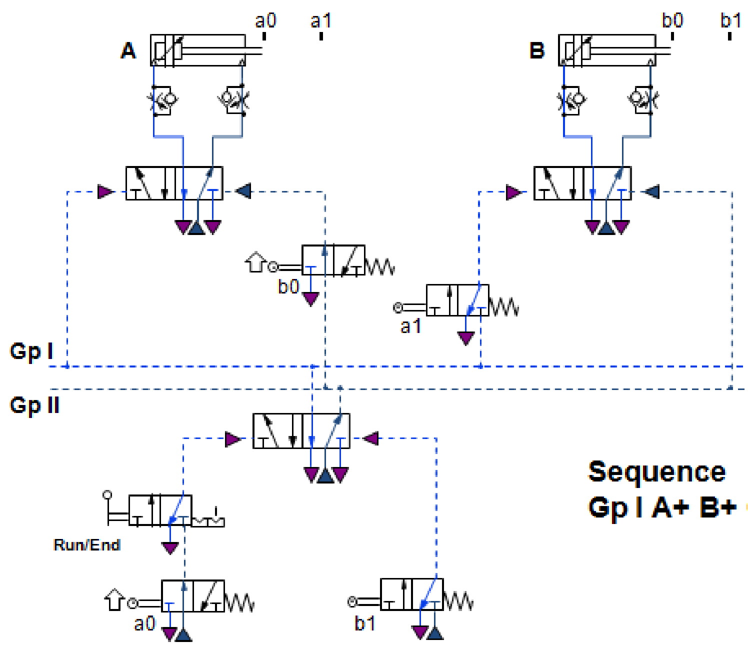
Cascade two group

- The A+ B+ B- A- circuit is solved by the two group cascade method
- The sequence is divided at the point where B immediately returns
- The two parts are allocated groups l and ll
- Gp l A+ B+ / Gp ll B- A-
- Two signal supplies are provided from a 5/2 valve one is available only in group l the other is available only in group ll
- Because only one group output is available at a time it is not possible to have opposed signals

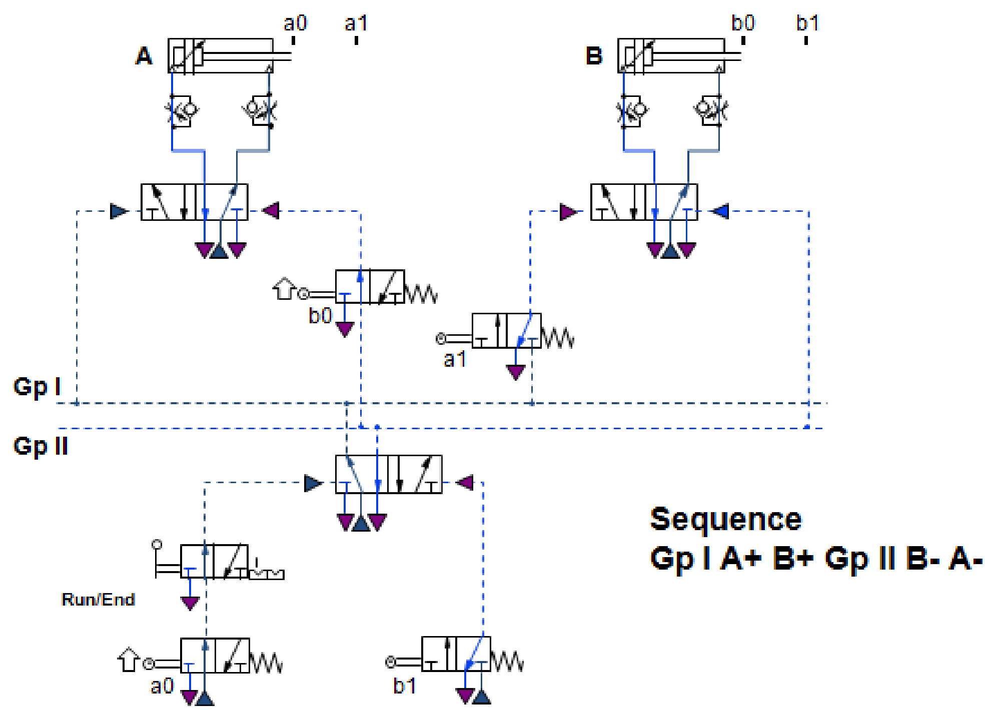
- A standard 5/2 double pressure operated valve is the cascade valve

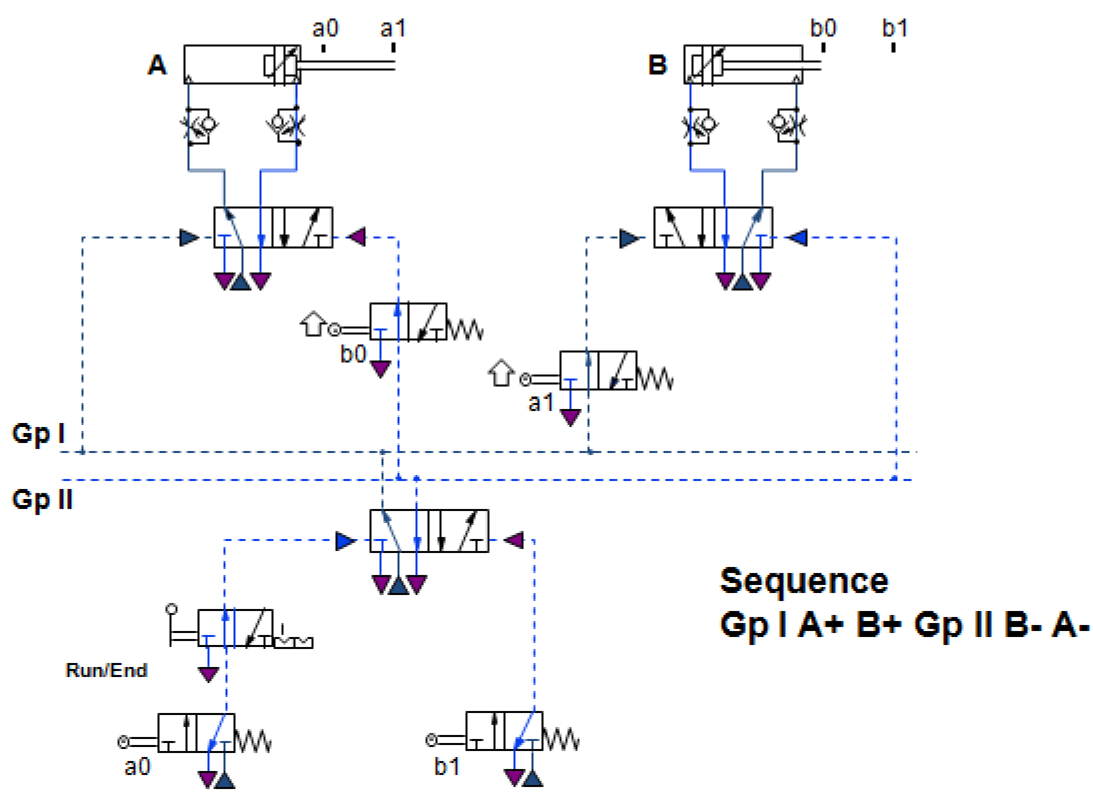


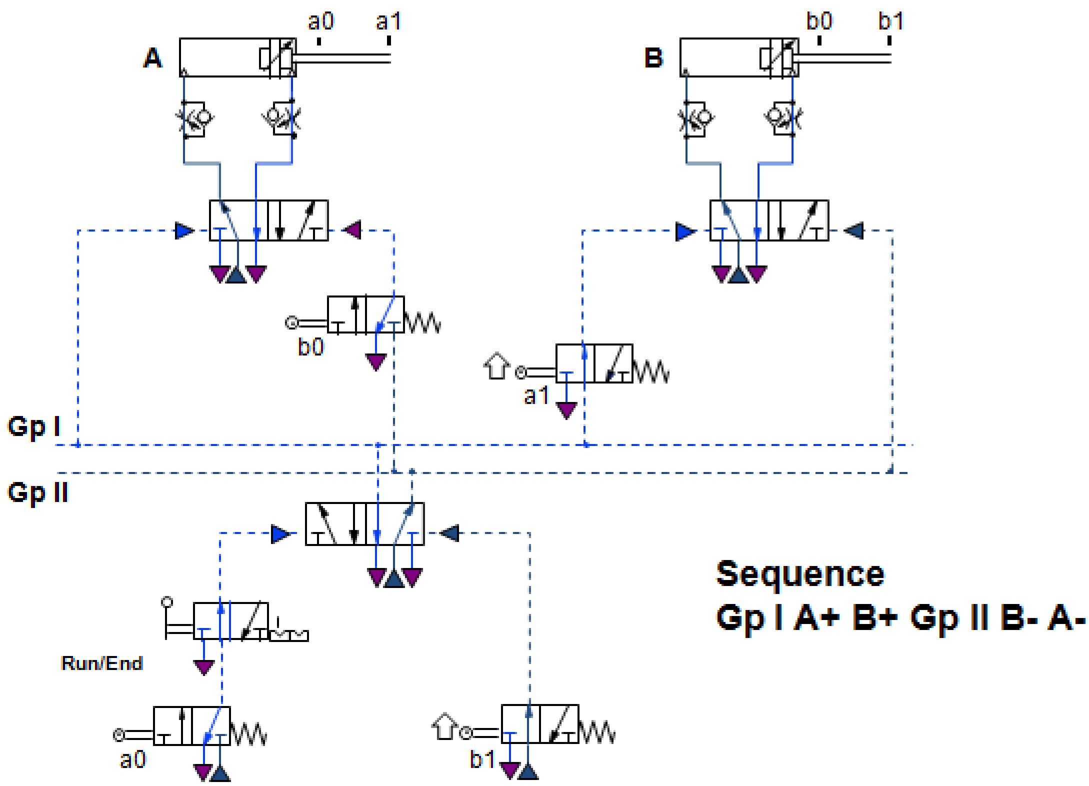
<u>Cascade (two group)</u>

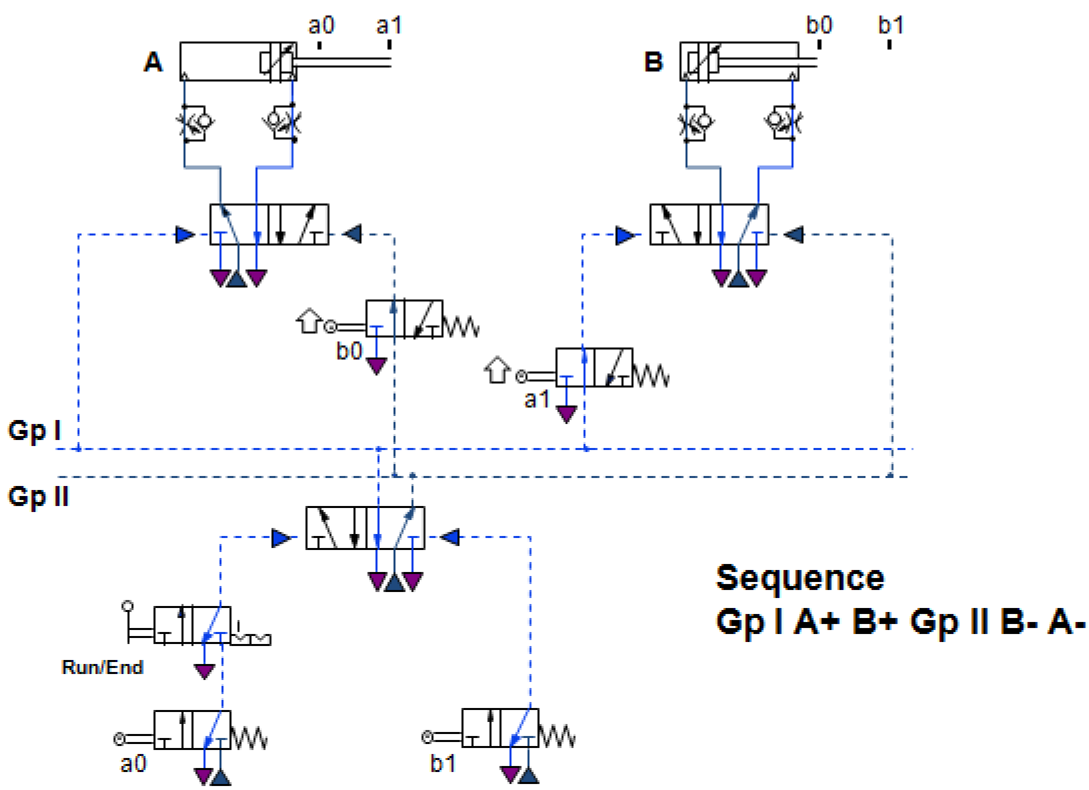


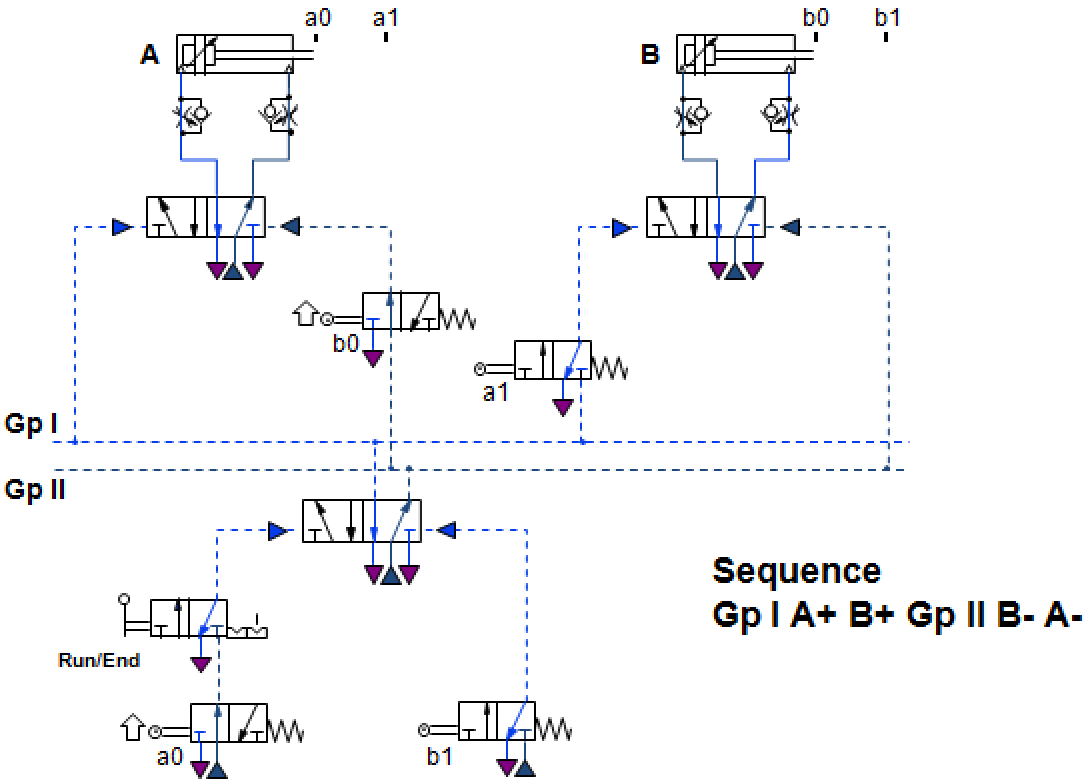
Sequence
Gp I A+ B+ Gp II B- A-


a0
a1
b0
b1
A
B
b0
a1
Gp I
Gp II
Run/End
a0
b1
Sequence
Gp I A+ B+ Gp II B- A-


a0
a1
b0
b1
A
B
b0
a1
Gp I
Gp II
Run/End
a0
b1
Sequence
Gp I A+ B+ Gp II B- A-

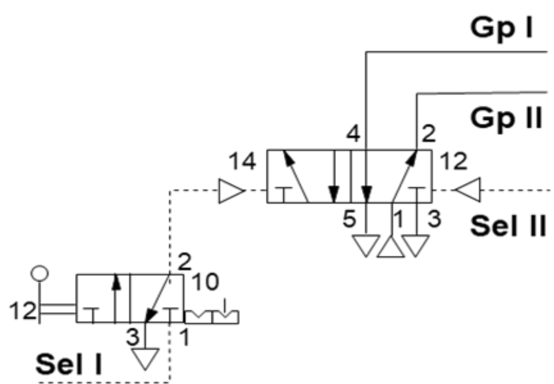

A
a0
a1
B
b0
b1
b0
a1
Gp I
Gp II
Run/End
a0
b1
Sequence
Gp I A+ B+ Gp II B- A-


A
a0
a1
B
b0
b1
b0
a1
Gp I
Gp II
Run/End
a0
b1
Sequence
Gp I A+ B+ Gp II B- A-

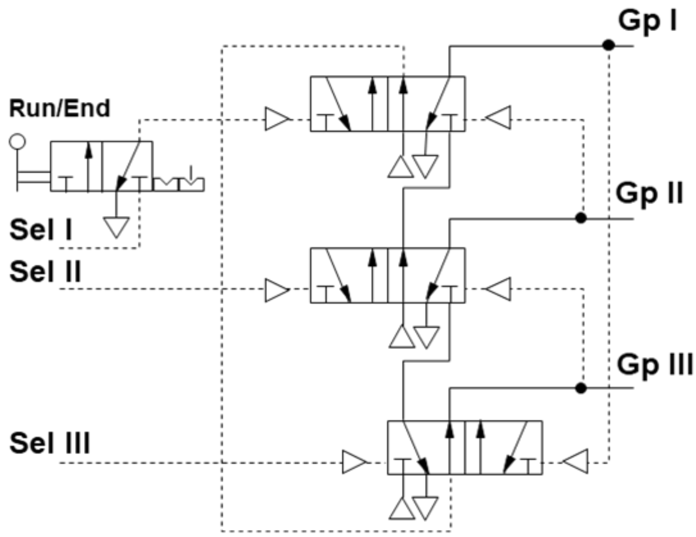


Cascade building blocks

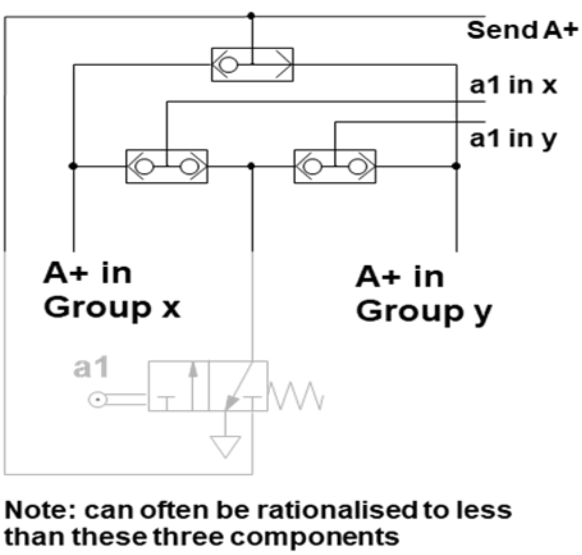
- A two group building block consists of a lever valve to run and end the sequence plus the 5/2 double pilot operated cascade valve
- For a two group system consisting of any number of cylinders this building block and the cylinder building blocks are all that is required to solve the sequence



- This three group building block establishes an interconnecting pattern that can be extended to any number of groups



- When a sequence has a cylinder operating twice in one overall sequence a dual trip building block may be required for each of the two feedback valves
- The supply will be from different groups and the output go to different destinations
- Example is for feedback valve a1 of cylinder A when A is sent + both in Group x and Group y



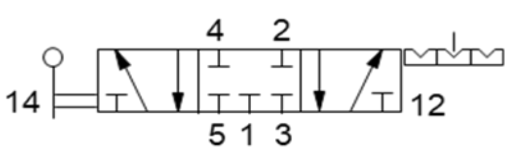
<u>Cascade rules</u>

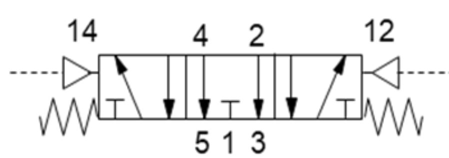
- Establish the correct sequence
- Divide the sequence in to groups. Always start a sequence with the Run/End valve selecting group I e.g.
  R/E | A+ B+ | B- C+ | C- A-
- Select the cylinder building blocks
- Select the cascade building block
- Select dual trip building blocks if required
- Interconnect the blocks as follows:
- The first function in each group is signalled directly by that group supply
- The last trip valve operated in each group is supplied with main supply air and selects the next group
- The remaining trip valves are supplied with air from their respective groups and initiate the next function
- The “run/end” valve will control the signal from the last trip valve to be operated

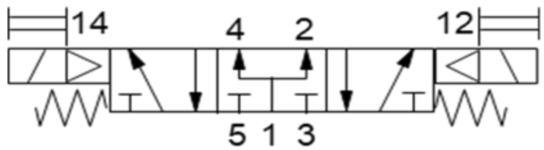
<u>Three position valves</u>

5/3 Valve

- 5/3 valves have a third mid position
- The valve can be tri-stable e.g. a detented lever operator or mono-stable e.g. a double air or double solenoid with spring centre
- There are three common configurations for the mid position:
  - All ports blocked
  - Centre open exhaust
  - Centre open pressure
- The majority of applications are actuator positioning and safety

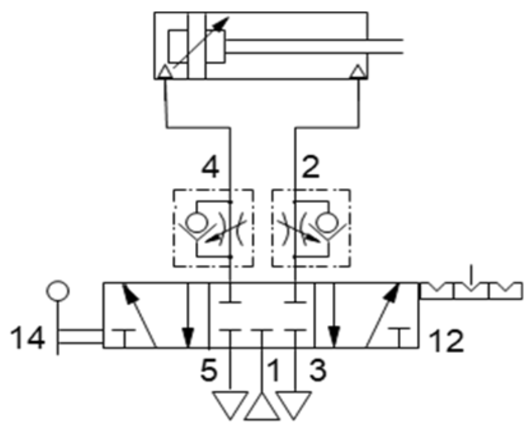






5/3 Valve actuator control

- The valve illustrated has “all ports blocked” in the mid position
- Whenever the mid position is selected the pressure conditions in the cylinder will be frozen
- This can be used to stop the piston at part stroke in some positioning applications
- Flow regulators mounted close to the cylinder to minimise creep



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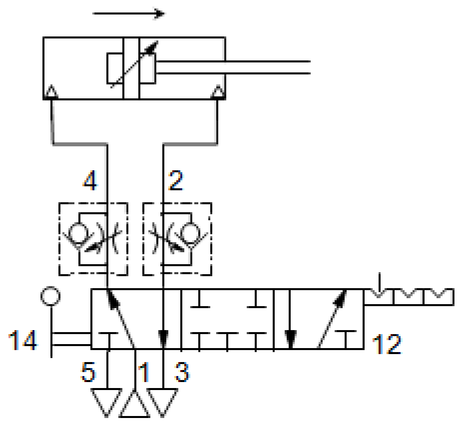

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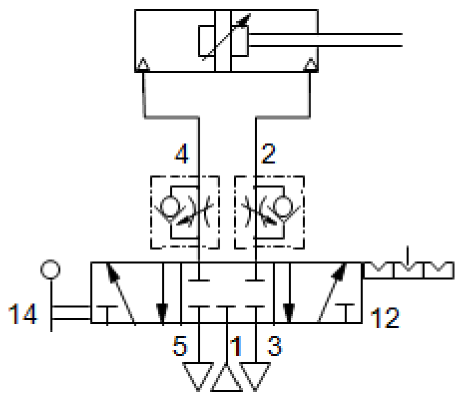

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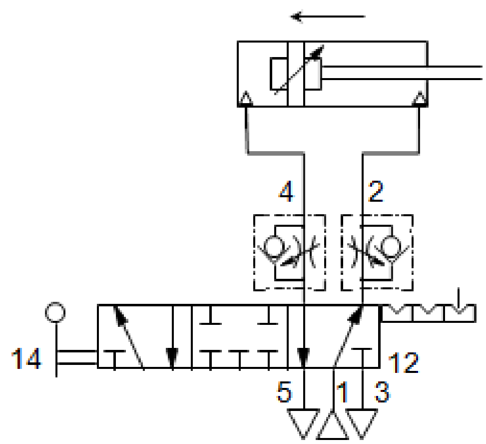

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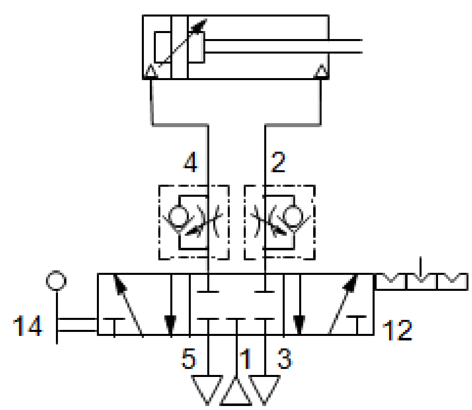
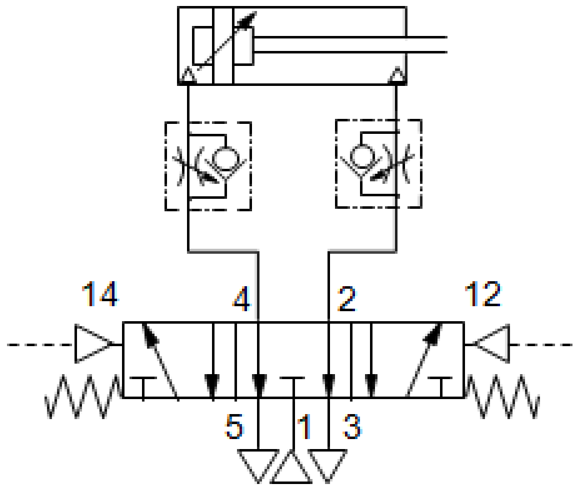
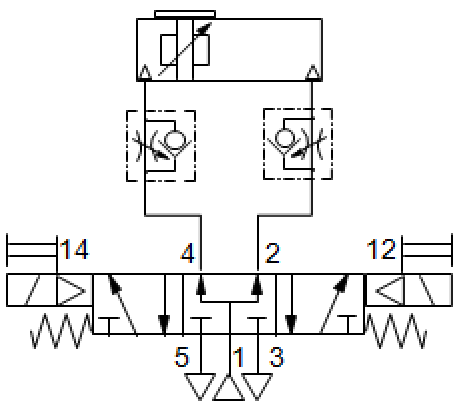


- This version of a 5/3 valve is “centre open exhaust”
- The supply at port 1 is isolated and the cylinder has power exhausted when this centre position is selected
- The version illustrated shows a mono-stable version double pilot operated spring centre
- The cylinder will be pre-exhausted when changing from the mid position



- This version of a 5/3 valve is “centre open pressure”
- The supply at port 1 is connected to both sides of the cylinder and the exhaust ports isolated when this centre position is selected
- Can be used to balance pressures in positioning applications
- The version illustrated is mono-stable, double solenoid, spring centre



Electro – Pneumatic Control

Introduction to Electro pneumatic Circuits

In electro pneumatic circuits the components generating, detecting and processing the signals (pushbuttons, limit switches and logic elements) have an electric operation, while the cylinders and the relevant distributors use the pneumatic energy.

Electro-pneumatic system is still pneumatic system in essence, which means that it has the main five components of a pneumatic system.

1. Supply elements
2. Input elements
3. Processing elements
4. Final control elements
5. Power elements (actuators

An important concept in electro-pneumatic systems is the ladder diagram. This diagram is a graphical representation of the electrical part of the electro-pneumatic system. It reflects your way of thinking. So in order to build an electro-pneumatic system, you have to start with putting the ladder diagram.

Electro pneumatics is now commonly used in many areas of Industrial low cost automation. They are also used extensively in production, assembly, pharmaceutical, chemical and packaging systems. There is a significant change in controls systems. Relays have increasingly been replaced by the programmable logic controllers in order to meet the growing demand for more flexible automation.

Electro-pneumatic control consists of electrical control systems operating pneumatic power systems. In this solenoid valves are used as interface between the electrical and pneumatic systems. Devices like limit switches and proximity sensors are used as feedback elements.

Electro Pneumatic control integrates pneumatic and electrical technologies, is more widely used for large applications. In Electro Pneumatics, the signal medium is the electrical signal either AC or DC source is used. Working medium is compressed air. Operating voltages from around 12 V to 220 Volts are often used. The final control valve is activated by solenoid actuation.

A Programmable Logic Controller can be conveniently used to obtain the out puts as per the required logic, time delay and sequential operation.. Finally the output signals are supplied to the solenoids activating the final control valves which control the movement of various cylinders. The greatest advantage of electro pneumatics is the integration of various types of proximity sensors [electrical] and PLC for very effective control. As the signal speed with electrical signal, can be much higher, cycle time can be reduced and signal can be conveyed over long distances.

In Electro pneumatic controls, mainly three important steps are involved:

- **Signal input devices** -Signal generation such as switches and contactor, Various types of contact and proximity sensors
- **Signal Processing** – Use of combination of Contactors of Relay or using Programmable Logic Controllers.
- **Signal Out puts** – Out puts obtained after processing are used for activation of solenoids, indicators or audible alarms.

This results in the realization of two different circuits representing:

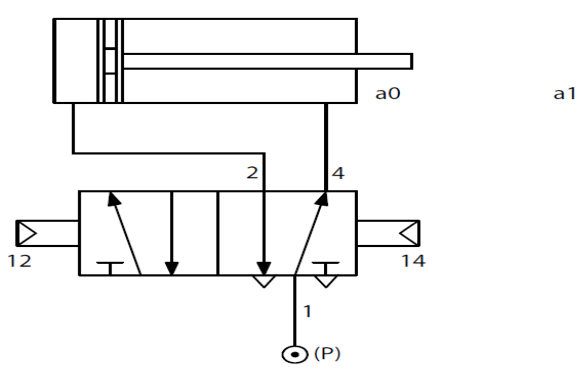


Fig87 The pneumatic circuit, the power

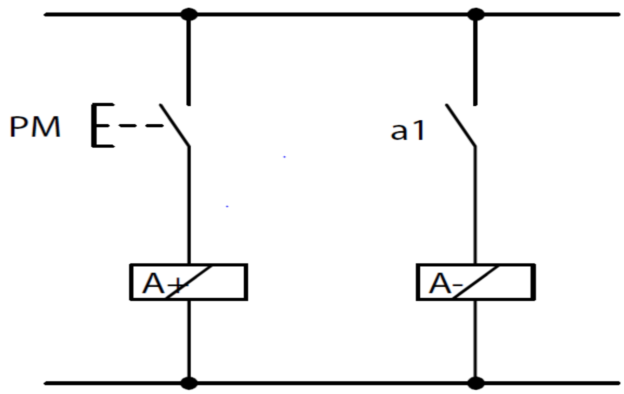
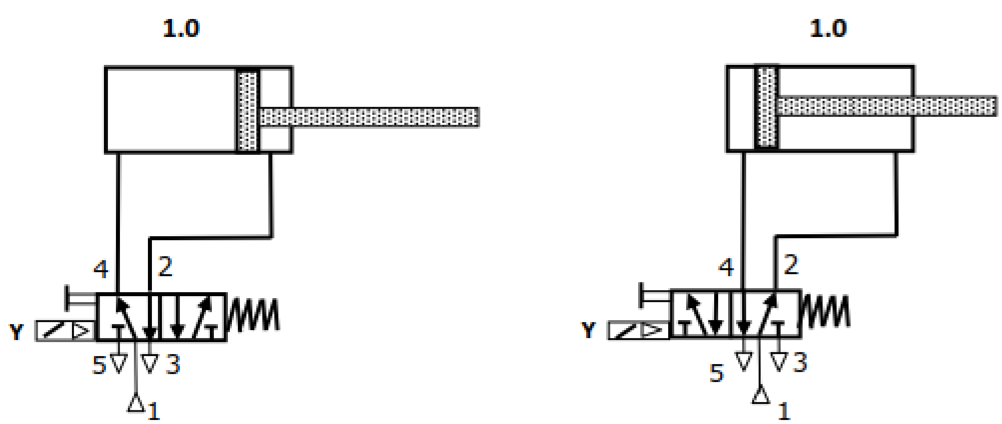
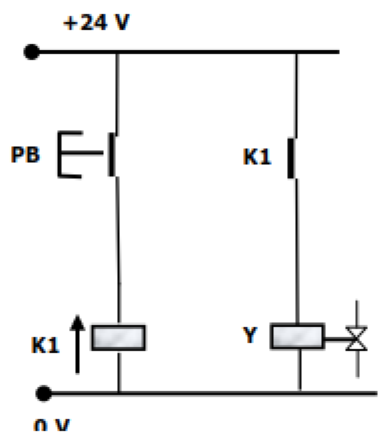
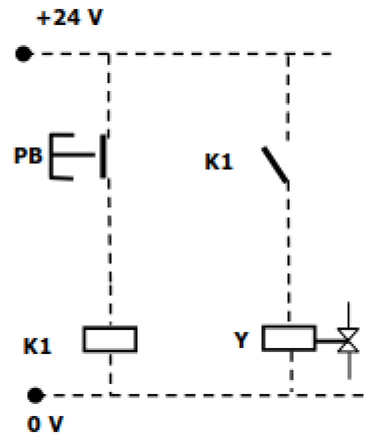


Fig 88 The electric circuit, the signal control and processing

Indirect control of double acting cylinder (using 5/2 way, single solenoid) with electrical control





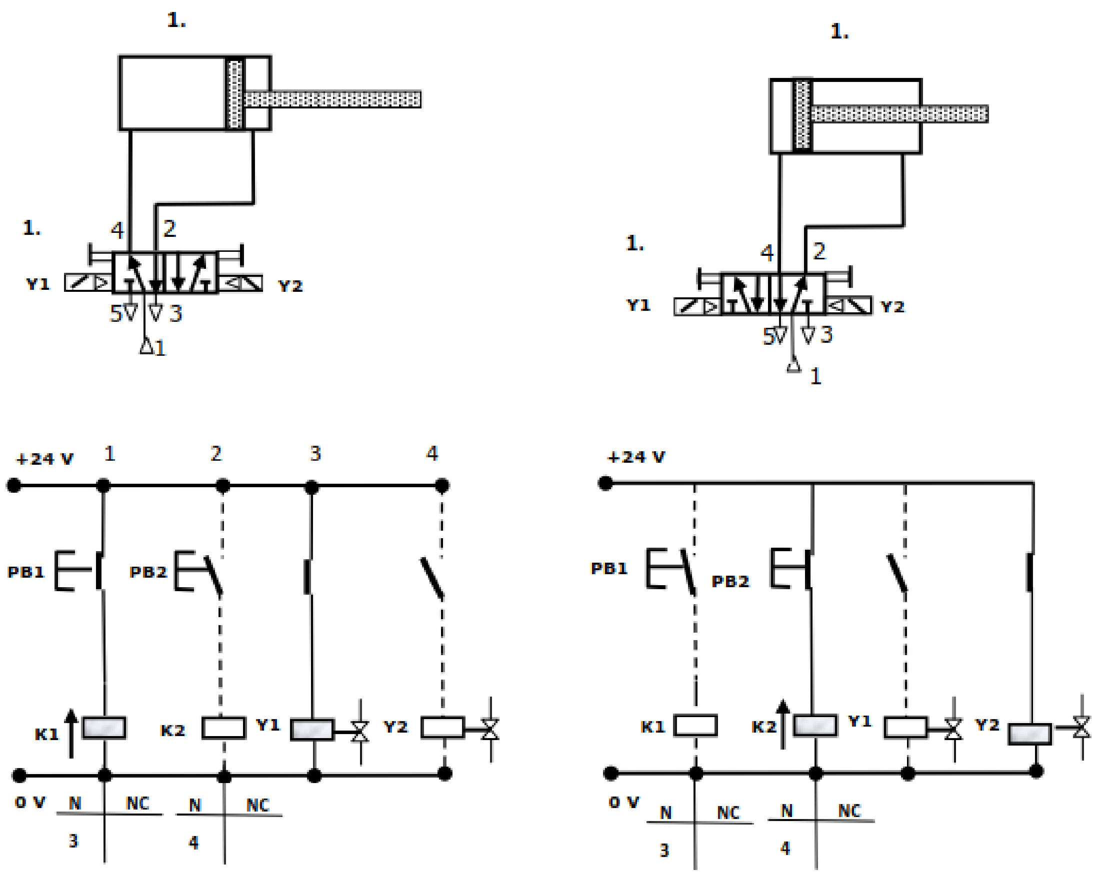


a) Position when cylinder is extended *b) Position when cylinder is retracted*

Forward stroke: The circuit is closed when push button PB closes. Closing of Push button PB energizes a relay K1. The coil Y is energized via normally open contact K1 (indirect energizing). A magnetic field is produced in armature of the coil Y opens the passage for the compressed air through internal pilot. The compressed air flows from 1 to 4 of the 5/2 DCV to cylinder, which travels to the final forward position.

Return stroke: When the push button PB is released, the circuit is interrupted. Opening of Push button PB de-energizes a relay K1. The magnetic field at coil Y is collapses due to the opening of contact K1 the 5/2 way valve switches back to its original position as shown in the above Figure. The compressed air in the cylinder then exhausts through port 5 of the DCV and the cylinder travel to the final rear position.

Indirect Control of double acting cylinder (using 5/2 way, double solenoid)

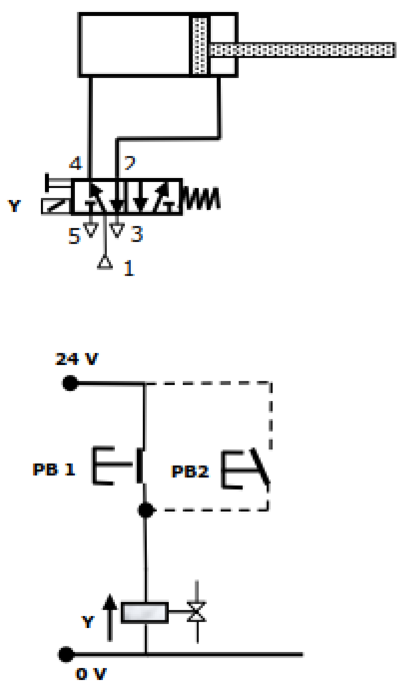


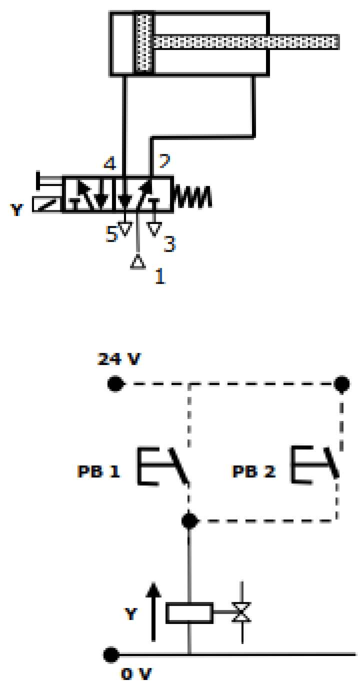
a) Position when cylinder is extended b) Position when cylinder retracted

Forward stroke: when push button PB1 is pressed, coil Y1 is energized and 5/2 way directional control valve changes over. The piston travels out and remains in the final forward position until a signal is applied to coil Y2. The 5/2 directional control valve will remain in the last position because it is double solenoid valve and has no return spring.

Return stroke: When the push button PB1 is released and PB2 is pressed. Opening of Push button PB1 de-energizes a relay K1. The magnetic field at coil Y1 is collapses due to the opening of contact K1. Closing of PB2 energizes Y2 and the piston returns to its original position as a result of changeover of the 5/2 way valve. The 5/2 way directional control valve will not switch over if there is an active opposing signal. For example, if Y1 is switched on and a signal is given to Y2, there will be no reaction as there would be an opposing signal

Control of double acting cylinder OR logic (Parallel circuit)

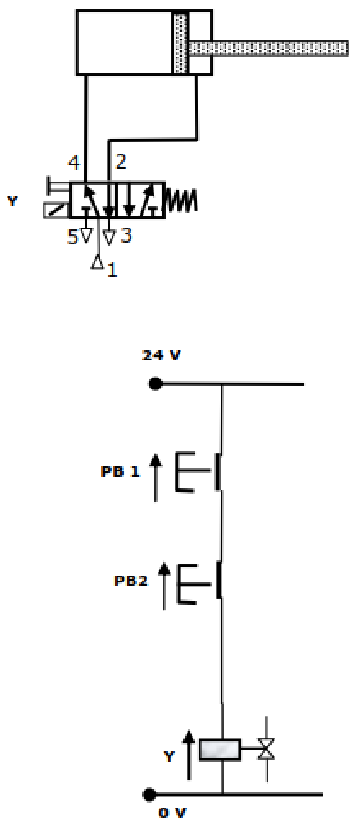




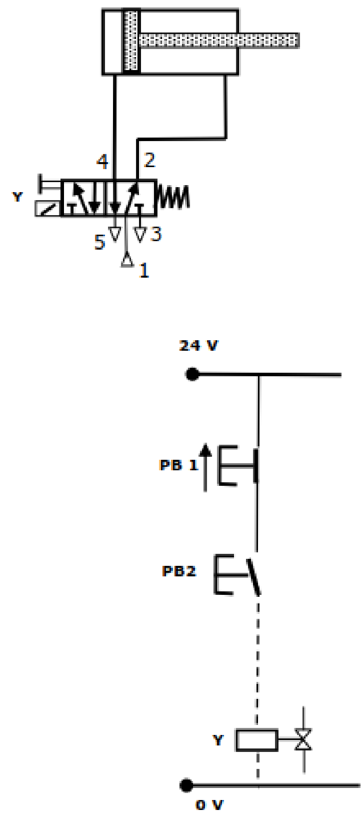
a) Cylinder is extended using PB1 b) Cylinder is retracted (both PB released)b)

The piston of a double acting cylinder is to travel out when either one of two pushbutton switch is pressed. It is to return when both are released. When push button PB1 or PB2 are pressed. Coil Y1 is energized. The directional control valve switches over and the piston travels to the final forward position. When both the push button switches are released, the signal is removed from Y1 and the cylinder travels back to its original position.

Control of double acting cylinder AND logic



a) Cylinder is extended using PB1



b) Cylinder is retracted (both PB released)

Latching circuits

Double acting cylinder is to be controlled using 5/2 directional control valve , single solenoid, spring return. When push button PB1 is pressed, cylinder should extend and remains in that position when PB1 is released. The cylinder is to retract completely when PB2 is pressed. In addition, the cylinder is to remain in the retracted postion even when PB2 is released. Develop a Electro-pneumatic control circuit with an electrical latching with a) dominant off b) dominant On

Solution

In the following pneumatic circuit a double acting cylinder is controlled by 5/2 way valve. When Y1 is energized cylinder moves forward. When Y1 is de energized cylinder retracts to its initial position.

We can construct the latching circuit using the following electrical components

1. Use NO pushbutton for ON or Start button control
2. Use NC push button for the OFF or stop control
3. Use a relay

Latching circuit can be dominant ON or dominant Off. Dominant position refer to status of relay coil (circuit) when both the start and stop signals are applied simultaneously

a) Latching circuit with Dominant OFF

When Start button (PB1) and Stop button (PB2) are pressed simultaneously, if the circuit goes to OFF position , then such a circuit is called Dominant OFF latching circuit. Refer to Figure bellow,

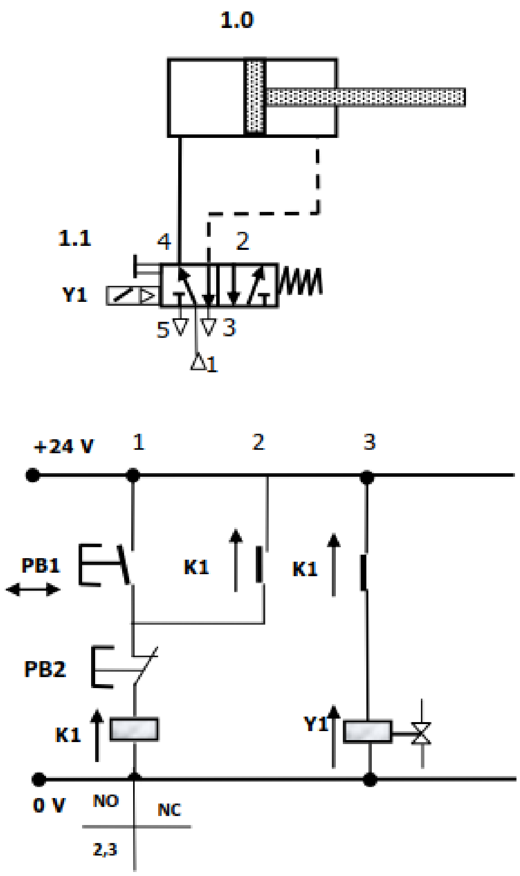
a) When we press START push button PB1 is pressed and released , following operations occurs:

1. Relay coil K1 in branch 1 (vertical) is energized. All Contact K1 closes
2. Notice that there is a NO contact of K1 in branch 2 , which is connected parallel to PB1. This NO contact of K1 latches the start push button. Therefore even if the PB1 is released, NO contact of K1 in branch 2 keeps coil K1 energized.
3. There is another NO contact in branch 3, which is connected to Y1. When push button PB1 is pressed this also remain closed, as a result cylinder moves forward and remains there until stop button PB2 is pressed.

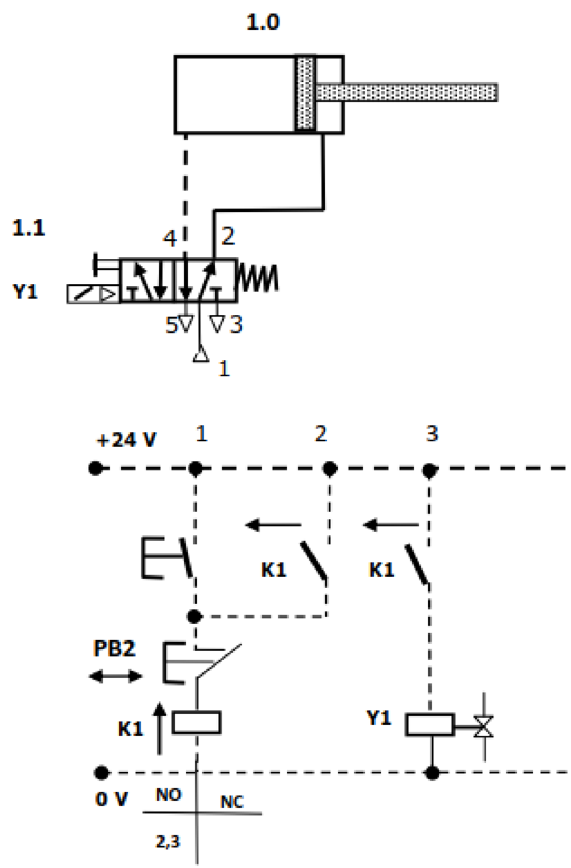
b) When we press STOP push button PB2 is pressed momentarily and released , following

operations occurs:

1. Relay coil K1 in branch 1 (vertical) is de-energized. All Contact K1 opens
2. NO contact of K1 in branch 2 , which is connected parallel to PB1 is now open. This NO contact of K1 no more latches the start push button.
3. NO contact in branch 3 is also open now, which is energizes. As a result cylinder moves back to its home position and remains there until start button PB1 is pressed again. When Start button (PB1) and Stop button (PB2) are pressed simultaneously, K1 contacts are open and the circuit goes to OFF position . That is why this circuit is called Dominant OFF latching circuit.



a) Circuit is in latched position



b) Circuit is in unlatched position

b) Latching circuit with Dominant ON

When Start button (PB1) and Stop button (PB2) are pressed simultaneously, if the circuit goes to ON

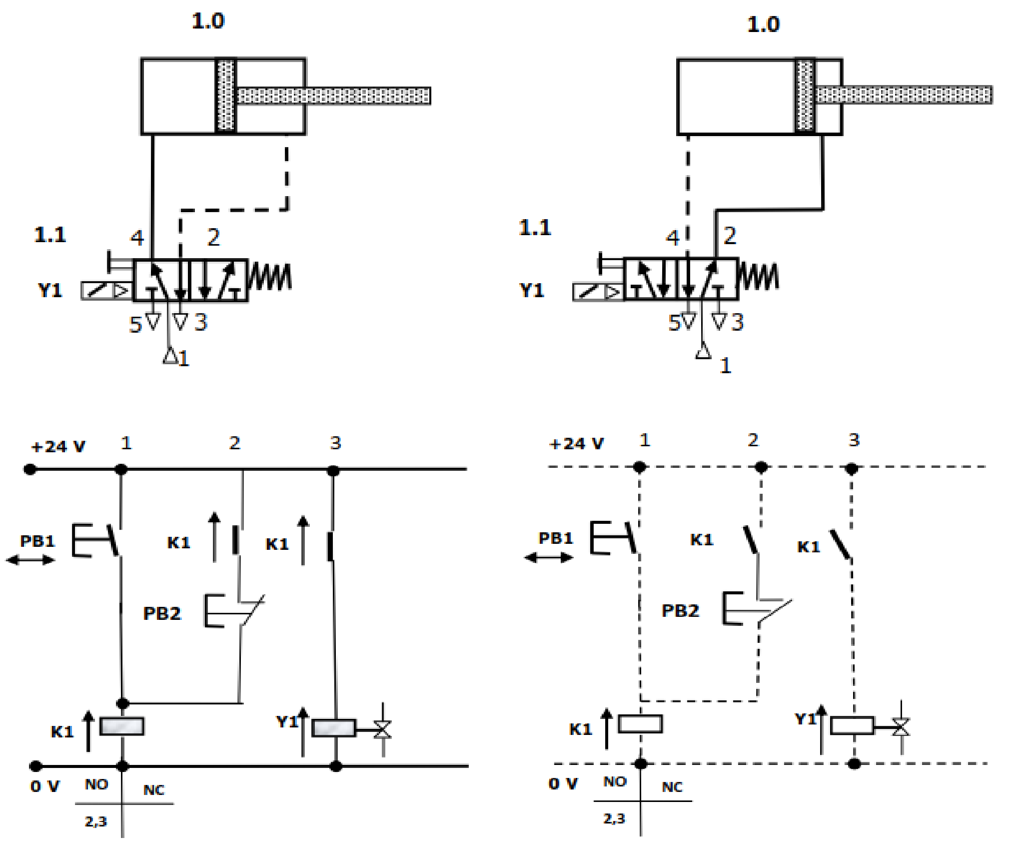
position , then such a circuit is called Dominant ON latching circuit. Refer to Figure bellow ,

a) When we press START push button PB1 is pressed and released , following operations occurs:

4. Relay coil K1 in branch 1 (vertical) is energized. All Contact K1 closes
5. Notice that there is a NO contact of K1 in branch 2 , which is connected parallel to PB1 and in series with PB2. This NO contact of K1 latches the start push button. Therefore even if the PB1 is released, NO contact of K1 in branch 2 keeps coil K1 energized.
6. There is another NO contact in branch 3, which is connected to Y1. When push button PB1 is pressed this also remain closed, as a result cylinder moves forward and remains there until stop button PB2 is pressed.

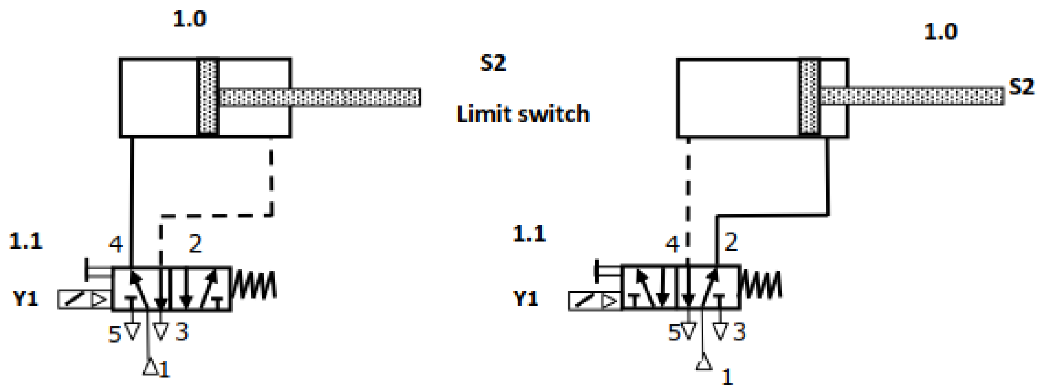
b When we press STOP push button PB2 is pressed momentarily and released , following operations occurs:

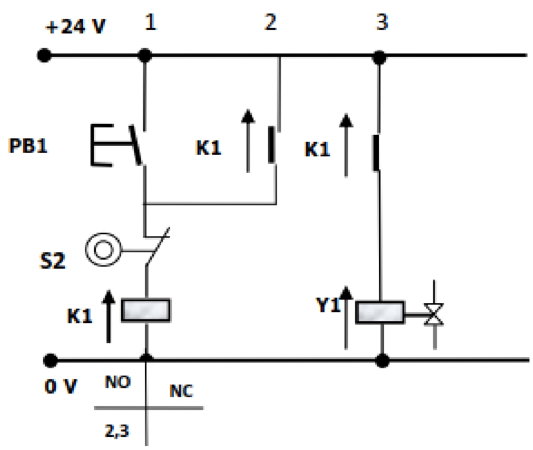
1. Relay coil K1 in branch 1 (vertical) is de-energized. All Contact K1 opens
2. NO contact of K1 in branch 2 , which is connected parallel to PB1 is now open. This NO contact of K1 no more latches the start push button.
3. NO contact in branch 3 is also open now, which is energizes. As a resutl cylinder moves back to its home position and remains in home position until start button PB1 is pressed again. When Start button (PB1) and Stop button (PB2) are pressed simultaneously, K1 contacts are open and the circuit goes to OFF position . That is why this circuit is called Dominant OFF latching circuit.



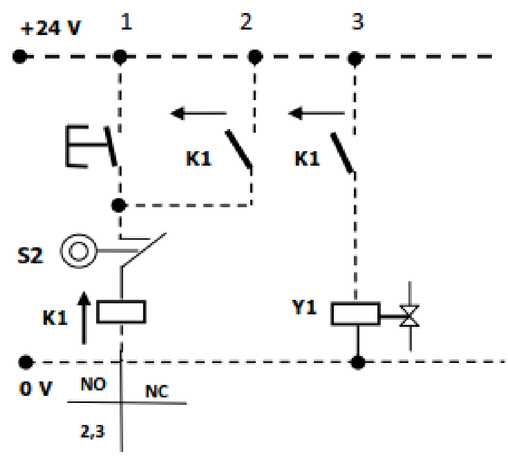
a) Circuit is in latched position b) Circuit is in unlatched position

Automatic return of a double acting cylinder (spring return)





a) Cylinder while extending



b) Position when S2 just pressed

Assignment

Create a PLC ladder and FBD diagrams for the Boolean expressions in the following problems.

a) $Y = (A' + B) + (A' + B + C')'$

b) $Y = A'B'C + AB' + A'BC'$

c) $Y = B'(A + C) + C(A' + B) + AC$

d) $Y = (A'B + AB') \times (A'B' + AB) + ABC$

Self-Check 2	Written Test

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

<u>Directions</u>: For the following questions, say TRUE if the statement is correct and FALSE if it is incorrect (wrong).

1. Ladder programs can be derived from Boolean expressions.
2. The decimal number system is a radix-10 number system.
3. Binary logic deals with variables that take on three discrete values.
4. The logic gate is the most basic building block of any digital system.
5. The output of an AND gate is HIGH only when one of its inputs are in the HIGH state.
6. In Ladder diagram, the power flow is taken to be from the left-hand vertical across a rung.
7. A function block is depicted as a rectangular block with inputs entering from the left and outputs emerging from the right.

. Answer the following question!

Note: Satisfactory rating 8 and14 points   Unsatisfactory below 8 and 14points

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

Score = ___________
Rating: ____________

Answer Sheet

Name: _________________________   Date: ____________

Operation title: convert forward reverse starting circuit of three phase induction motor into functional block diagram using PLC programming software

Purpose	**The trainee will be able to convert wiring diagram into ladder diagram.**
Equipment ,tools and materials	Supplies and equipment needed or useful for convert wiring diagram into ladder diagram. include these: • PLC • Computer • Siemens software • Paper • Wiring diagram • screw driver • Pliers • Digital Multi-tester
Conditions or situations for the operations	• All tools, equipment's and materials should be available on time when required. • Appropriate material, working area/ workshop to convert wiring diagram into ladder diagram.

Procedures	1. Apply OH&S PPE 2. convert the starting control circuit shown below in to ladder diagram 3. compile and test with simulation program 4. transfer the program to PLC 5. make the hard ware connection and run the PLC
Precautions	• Care should be taken while connecting with electric power, computer • Preparing materials, tools and equipment are according to inseminator command.
Quality criteria	• Did personal protective equipment worn • Did trainees compile and test with simulation program • Did the trainee transfer the program to PLC • Checks the circuit safely using proper instrument • Convert devices according to the given drawing • Installs electrical wiring according to the job requirements

Convert forward reverse starting circuit of three phase induction motor into ladder diagram using PLC programming software

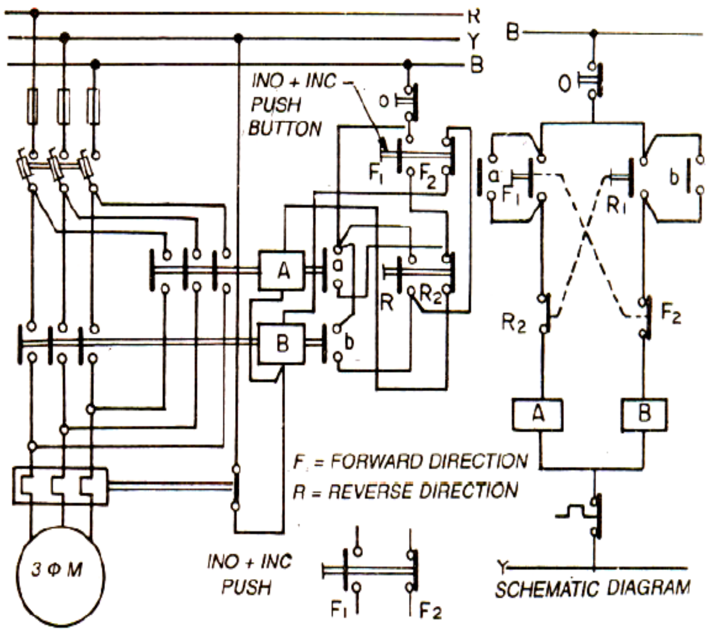
LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions:

1. You are required to perform any of the following:
   1.1. Prepare equipment and material for converting wiring diagram to ladder diagram
   1.2 convert the starting control circuit shown below in to ladder diagram
   1.3 exact simulation of the program performing with the control circuit given
   1.4 transfer the program to PLC
   1.5 make the hard ware connection and run the PLC
2. Request your teacher for evaluation and feedback



Information Sheet2 Testing Created/Modified basic PLC programs

4.1 Testing Created/Modified basic PLC programs

PLC Installation, Commissioning and Recommendations

Typical installation

- Typical installation (enclosure, disconnect device, fused isolation transformer, master control relay, terminal blocks and wiring ducts, suppression devices).
- Spacing controllers – follow the recommended minimum spacing to allow the convection cooling.
- Preventing excessive heat (0–60?) C

- Grounding guidelines.
- Power considerations.
- Safety considerations.
- Preventive maintenance considerations.

Commissioning and testing of a PLC system

- Checking that all cable connections between the PLC and the plant are complete, safe, and to the required specification and meeting local standards.
- Checking that all the incoming power supply matches the voltage setting for which the PLC is set.
- Checking that all protective devices are set to their appropriate trip settings.
- Checking that emergency stop button work.
- Checking that all input/output devices are connected to the correct input/output points and giving the correct signals.
- Loading and testing the software.

Testing inputs and outputs

Input devices can be manipulated to give the open and closed contact conditions and the corresponding LED on the input module observed. Forcing also can be used to test inputs and outputs. This involves software, rather than mechanical switching on or off, being used with instructions to turn off or on inputs/outputs.

Testing Software

Most PLCs contain some software checking program. This checks through the installed program and provides a list on a screen or as printout with any errors detected.

While the PLC is running, the scanning process includes the following four phases, which are repeated continuously as individual cycles of operation:

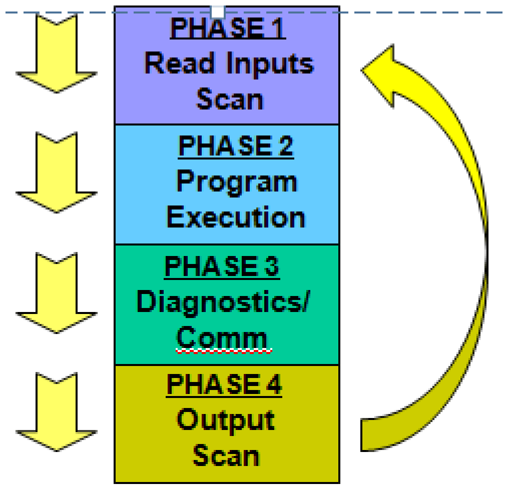


Fig 90 Scanning process phases

- **Phase 1** – Input Status scan
  - ✓ A PLC scan cycle begins with the CPU reading the status of its inputs.
- **Phase 2**– Logic Solve/Program Execution
  - ✓ The application program is executed using the status of the inputs
- **Phase 3**– Diagnostics/ Comm.
  - ✓ Once the program is executed, the CPU performs diagnostics and communication tasks
- **Phase 4** - Output Status Scan
  - ✓ An output status scan is then performed, whereby the stored output values are sent to actuators and other field output devices. The cycle ends by updating the outputs
- As soon as Phase 4 are completed, the entire cycle begins again with Phase 1 input scan.

- The time it takes to implement a scan cycle is called SCAN TIME. The scan time composed of the program scan time, which is the time required for solving the control program, and the I/O update time, or time required to read inputs and update outputs. The program scan time generally depends on the amount of memory taken by the control program and type of instructions used in the program. The time to make a single scan can vary from 1 ms to 100 ms.

Four main steps that shows PLC working principle

Bringing input signal status to the internal memory of CPU

- As mentioned earlier, the field signals are connected to input module. At the output of input module the field status converted into the voltage level required by the CPU is always available.
- At the beginning of each cycle the CPU brings in all the field input signals from input module and stores into its internal memory as process image of input signal. This internal memory of CPU is called as PII, meaning Process Image Input.

The programmable controller operates cyclically meaning when complete program has been scanned; it starts again at the beginning of the program.

Processing of signal using program

Once the field input status is brought in to the internal memory of CPU i.e. in the PII, the execution of user program begins, statement by statement. Based on the user program the CPU performs logical and arithmetic operations on the data from PII. It also processes times and counts as well as flag states.

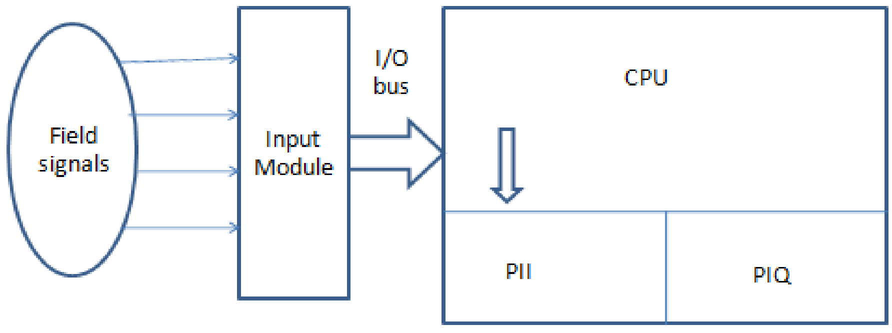


Fig91 Processing of signal using program

Storing the results of processing in the internal memory

- The results of the user program scan are then stored in the internal memory of CPU. This internal memory is called Process Output Image or PIQ

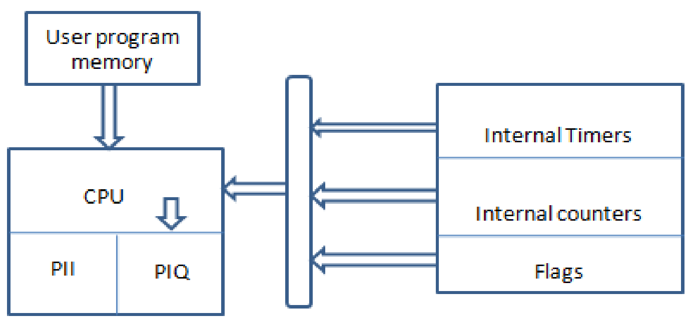


Fig 92 Storing the results of processing

➢ **Internal Relays (Flags)**

- Internal relays are imaginary programmed relays that are not connected to any real output but have coils and contacts. Since they are not addresses for real outputs, internal relays cannot have addresses that start with "Q".

- Instead they have addresses of the user selection that starts with "M" like "M0.0" or "M1.3".

- Of course there is a certain number of coils allowed to be programmed in SIMATIC S7 software which is 2048 internal relay. Internal relays have many uses.
- One of their common uses is the case when a certain condition must be used in the operation of more than one rung (network).

Sending process output to output module

- At the end of the program run i.e. at the end of scanning cycle, the CPU transfers the signal states in the process image output to the output module and further to field controls.

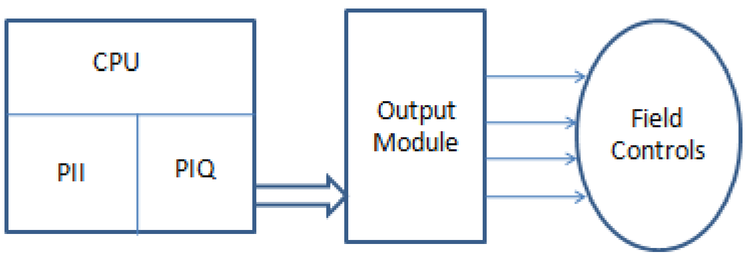


Fig93 : Sending process output to output module

Selecting a PLC

Several factors are used for evaluating the quality and performance of programmable controllers when selecting a unit for a particular application. These are listed below.

(a) Number of I /O Ports

This specifies the number of I/O devices that can be connected to the controller. There should be sufficient I/O ports to meet present requirements with enough spares to provide for moderate future expansion.

(b) Output-port Power Ratings

Each output port should be capable of supplying sufficient voltage and current to drive the output peripheral connected to it.

(c) Scan Time

This is the speed at which the controller executes the relay-ladder logic program. This variable is usually specified as the scan time per 1000 logic nodes and typically ranges from 1 to 200 ms

(d) Memory Capacity

The amount of memory required for a particular application is related to the length of the program and the complexity of the control system. Simple applications having just a few relays do not require significant amount of memory. Program length tends to expand after the system has been used for a while. It is advantageous to a acquire a controller that has more memory than is presently needed

List of items required when working with PLCs:

1. Programming Terminal - laptop or desktop PC.
2. PLC Software. PLC manufacturers have their own specific software and license key.
3. Communication cable for connection from Laptop to PLC.
4. Backup copy of the ladder program (on diskette, CDROM, hard disk, flash memory). If none, upload it from the PLC.
5. Documentation- (PLC manual, Software manual, drawings, ladder program printout, and Seq. of Operations manual.)

A Detailed Design Process

1. Understand the process
2. Hardware/software selection
3. Develop ladder logic
4. Determine scan times and memory requirements

PLC Status Indicators

- Power On
- Run Mode

- Programming Mode
- Fault

Self-Check - 2	Written Test

Directions: For the following questions, say TRUE if the statement is correct and FALSE if it is incorrect (wrong).

1. Ladder programs can be derived from Boolean expressions.
2. The decimal number system is a radix-10 number system.
3. Binary logic deals with variables that take on three discrete values.
4. The logic gate is the most basic building block of any digital system.
5. The output of an AND gate is HIGH only when one of its inputs are in the HIGH state.
6. In Ladder diagram, the power flow is taken to be from the left-hand vertical across a rung.
7. A function block is depicted as a rectangular block with inputs entering from the left and outputs emerging from the right

Note: Satisfactory rating 8 and above points, Unsatisfactory – below 8 points

Answer Sheet

Name: ____________________ Date: ____________

Score = ___________

Rating: ____________

Operation title: convert automatic star delta starting circuit of three phase induction motor into functional block diagram using PLC programming software

Purpose	The trainee will be able to convert wiring diagram into functional block diagram**.**
Equipment ,tools and materials	Supplies and equipment needed or useful for convert wiring diagram into functional block diagram**.** include these: • PLC • Computer • Siemens software • Paper • Wiring diagram • screw driver • Pliers • Digital Multi-tester
Conditions or	• All tools, equipment's and materials should be available on time

situations for the operations	when required. • Appropriate material, working area/ workshop to convert wiring diagram into functional block diagram.
Procedures	6. Apply OH&S PPE 7. convert the starting control circuit shown below in to ladder diagram 8. compile and test with simulation program 9. transfer the program to PLC 10. make the hard ware connection and run the PLC
Precautions	• Care should be taken while connecting with electric power, computer • Preparing materials, tools and equipment are according to inseminator command.
Quality criteria	• Did personal protective equipment worn • Did trainees compile and test with simulation program • Did the trainee transfer the program to PLC • Checks the circuit safely using proper instrument • Convert devices according to the given drawing • Installs electrical wiring according to the job requirements

Convert automatic star delta starting circuit of three phase induction motor into functional block diagram using PLC programming software

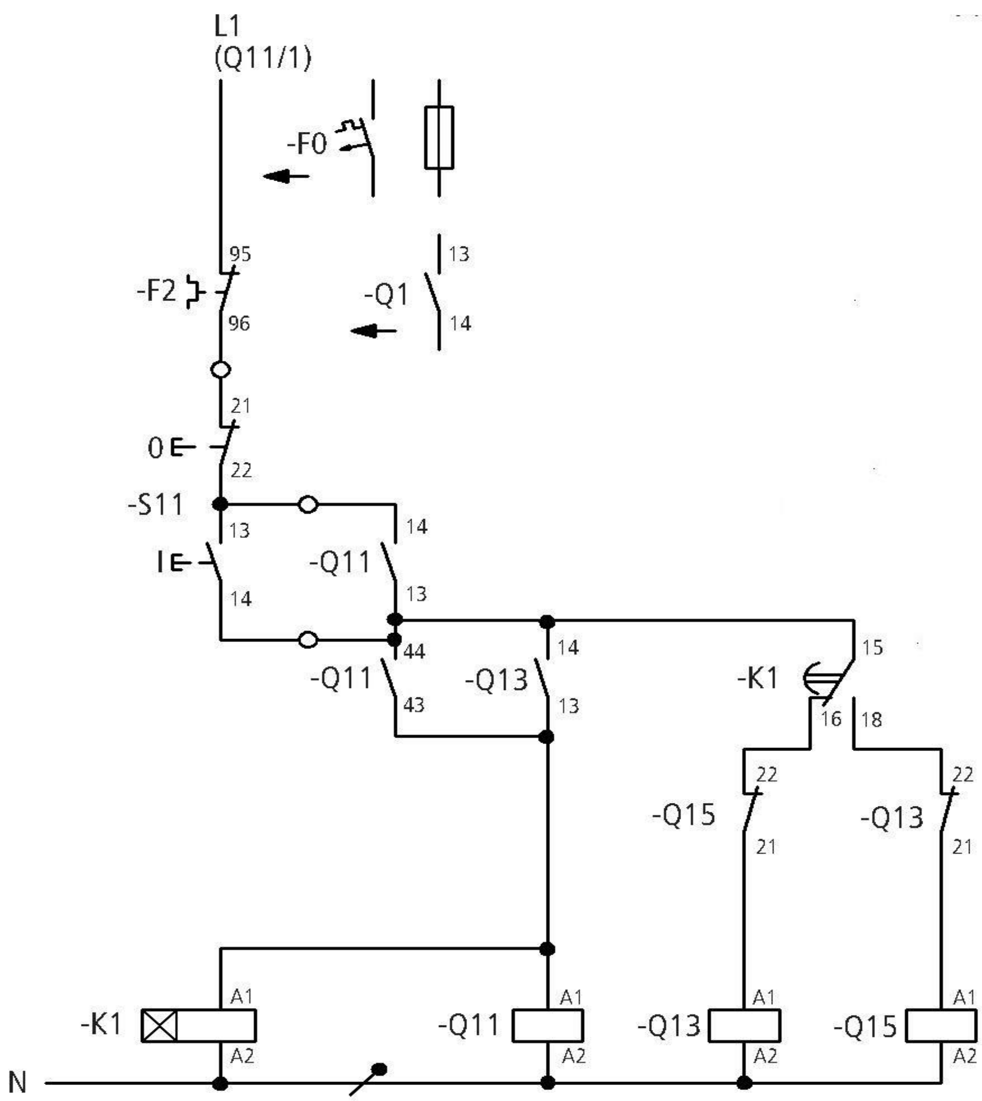
LAP Test	Practical Demonstration

Name: ______________________________ Date: ________________

Time started: ________________________ Time finished: ________________

Instructions:

1. You are required to perform any of the following:
   1.2. Prepare equipment and material for converting wiring diagram to functional block diagram
   1.6 convert the starting control circuit shown below in to ladder diagram
   1.7 exact simulation of the program performing with the control circuit given
   1.8 transfer the program to PLC
   1.9 make the hard ware connection and run the PLC
2. Request your teacher for evaluation and feedback


L1
(Q11/1)
-F0
95
-F2
96
13
-Q1
14
21
0
22
-S11
13
I
14
14
-Q11
13
44
-Q11
43
14
-Q13
13
15
-K1
16
18
22
-Q15
21
22
-Q13
21
-K1
A1
A2
-Q11
A1
A2
-Q13
A1
A2
-Q15
A1
A2
N

Information Sheet- 3 Reviewing tested process to ensure defect-free PLC program Text Processes

1.1 Reviewing tested process to ensure defect-free PLC program Text Processes

PLC System Maintenance

Programmable controllers are designed to be easy to maintain, to ensure trouble-free operation. Still, several maintenance aspects should be considered once the system is in place and operational. Certain maintenance measures, if performed periodically, will minimize the chance of system malfunction.
This section outlines some of the practices that should be followed to keep the system in good operating condition.

Preventive maintenance

Preventive maintenance of programmable controller systems includes only a few basic procedures, which will greatly reduce the failure rate of system components.
Preventive maintenance for the PLC system should be scheduled with the regular machine or equipment maintenance, so that the equipment and controller are down for a minimum amount of time.
However, the schedule for PLC preventive maintenance depends on the controller's environment— the harsher the environment, the more frequent the maintenance. The following are guidelines for preventive measures:

- ❖ Periodically clean or replace any filters that have been installed in enclosures at a frequency dependent on the amount of dust in the area.
- ❖ Do not allow dirt and dust to accumulate on the PLC's components; the central processing unit and I/O system are not designed to be dust proof. If dust builds

up on heat sinks and electronic circuitry, it can obstruct heat dissipation, causing circuit malfunction.

- ❖ Periodically check the connections to the I/O modules to ensure that all plugs, sockets, terminal strips, and modules have good connections. Also, check that the module is securely installed.
- ❖ Ensure that heavy, noise-generating equipment is not located too close to the PLC.
- ❖ Make sure that unnecessary items are kept away from the equipment inside the enclosure. Leaving items, such as drawings, installation manuals, or other materials, on top of the CPU rack or other rack enclosures can obstruct the airflow and create hot spots, which can cause system malfunction.
- ❖ If the PLC system enclosure is in an environment that exhibits vibration, install a vibration detector that can interface with the PLC as a preventive measure. This way, the programmable controller can monitor high levels of vibration, which can lead to the loosening of connections.

Fault detection techniques

For any PLC controlled plant, by far the greater percentage of the faults are likely to be with sensors, actuators, and wiring rather than with PLC itself. The faults within the PLC most are likely to be in the input/output channels or power supply than in the CPU.

Diagnostic indicators

- o LED status indicators can provide much information about field devices, wiring, and I/O modules. Most input/output modules have at least a single indicator—input modules normally have a power indicator, while output modules normally have a logic indicator.
- o For an input module, a lit power LED indicates that the input device is activated and that its signal is present at the module. This indicator alone cannot isolate malfunctions to the module, so some manufacturers provide an additional diagnostic indicator, a logic indicator.

- LED indicators greatly assist the troubleshooting process. With both power and logic indicators, the user can immediately pinpoint a malfunctioning module or circuit. LED indicators, however, cannot diagnose all possible problems; instead, they serve as preliminary signs of system malfunctions**.**

Case 1

Consider a single output device failing to turn on though the output LED is on.
If testing of the PLC output voltage indicates that it is normal then the fault might be a wiring fault or a device fault. If checking of the voltage at the device indicates the voltage there is normal then the fault is the device.

Case 2

Failure of an input LED to illuminate as required could be because

- Input device is not correctly operating,
- input device is not correctly powered,
- Incorrect wiring connections to the input modulle, or LED or input module is defective.

Many plc provide built in fault analysis procedure which carry out self testing and display fault codes, with possibly a brief message which can be translated by looking up code in a list to give the source of the fault and possible method of recovery

Troubleshooting

Program troubleshooting

- There are severall causes off alteration to the userprogram:
- extreme environmental conditions,
- electromagnetic Interference (EMI),

- improper grounding,
- improper wiring connections, and Unauthorized tampering.
- If you suspect the memory has been altered, check the program against a previously saved program on an EEPROM, UVPROM or flash EPROM modulle.

Hardware troubleshooting

Tips for troubleshooting control system

- If installation and start-up procedures were followed closely, controller will give reliable service.
- If a problem should occur, the first step in the troubleshooting procedure is to identify the problem and its source.
- Do this by observing your machine or process and by monitoring the diagnostic LED indicators on the CPU, Power Supply and I/O modules.

By observing the diagnostic indicators on the front of the processor unit and I/O modules, the majority of faults can be located and corrected. These indicators, along with error codes identified in the programming device user manual and programmer's monitor, help trace the source of the fault to the user's input/output devices, wiring, or the controller.

- **Troubleshooting Controller**
  In identifying the source of the controller's operation problem use troubleshooting considerations table including status indication, trouble description, probable causes and recommended action.

To receive the maximum benefit, follow these steps:

- Identify Power Supply and CPU LED status indicators;
- Match processor LEDs with the status LEDs located in troubleshooting tables;
- Once the status LEDs are matched to the appropriate table, simply

- move across the table identifying error description and probable causes;
- Follow the recommended action steps for each probable cause until the cause is identified;
- If recommended actions do not identify the cause, contact manufacturer or distributor for assistance.

Troubleshooting Input modules

An input circuit responds to an input signal in the following manner:

An input filter removes false signals due to contact bounce or electrical interference; Optical isolation protects the backplane circuits by isolating logic circuits from input signals; Logic circuits process the signal; An input LED turns on or off indicating the status of the corresponding input device.

The processor receives the input status for use in processing the program logic.

If the field device connected to an input module does not seem to turn ON, a problem may exist somewhere between the L1 connection and the terminal connection to the module. An input module's status indicators can provide information about the field device, the module, and the field device's wiring to the module that will help pinpoint the problem.

If the module does not read the field device's signal, then further tests are required. Bad wiring, a faulty field device, a faulty module, or an improper voltage between the field device and the module could be causing the problem. First, close the field device and measure the voltage to the input module

If the measured voltage is 10–15% below the proper signal voltage, then the problem lies in the source voltage to the field device.

If no voltage is present, then either the wiring or the field device is the cause of the problem. Check the wiring connection to the module to ensure that the wire is secured at the terminal or terminal blocks.

Troubleshooting Output modules

An output circuit controls the output signal in the following manner:

The processor determines the output status; Logic circuits maintain the output status.

An output LED indicates the status of the output signal, Optical isolation separates logic and backplane circuits from field signals;

The output driver turns the corresponding output on or off.

PLC output interfaces also contain status indicators that provide useful troubleshooting information. Like the troubleshooting of PLC inputs, the first step in troubleshooting outputs is to isolate the problem to either the module, the field device, or the wiring.

At the output module, ensure that the source power for switching the output is at the correct level.

If the output module receives the command to turn ON from the processor yet the module's output status does not turn ON accordingly, then the output module is faulty. If the indicator turns ON but the field device does not energize, check for voltage at the output terminal to ensure that the switching device is operational.

After checking the module, check that the field device is working properly. Measure the voltage coming to the field device while the output module is ON, making sure that the return line is well connected to the device. If there is power yet the device does not respond, then the field device is faulty.

Another method for checking the field device is to test it without using the output module. Remove the output wiring and connect the field device directly to the power source. If the field device does not respond, then it is faulty.

Replacement of I/O modules

- If a module must be replaced, the user should make sure that the replacement module being installed is the correct type. Some I/O systems allow modules to be replaced while power is still applied, but others may require that power be removed.

- If replacing a module solves the problem, but the failure re-occurs in a relatively short period, the user should check the inductive loads. The inductive loads may be generating voltage and current spikes, in which case, external suppression may be necessary.
- If the module's fuse blows again after it is replaced, the problem may be that the module's output current limit is being exceeded or that the output device is shorted.

Power distribution

The master control relay must be able to inhibit all machines motion by removing power to the machine I/O devices when the relay is de-energized. The DC power supply should be powered directly from the fused secondary of the transformer. Power to the DC input, and output, circuits is connected through a set of master control relay contacts. Interrupt the load side rather the AC line power. This avoids the additional delay of power supply turn-on and turn-off.

Power LED

The POWER LED on the power supplly indicates that DC power is being supplied to the chassis. This LED could be off when incoming power is present when the:
Fuse is blown;
Voltage drops below the normal operating range;
Power supply is defective.

Troubleshooting the CPU

- PLCs also provide diagnostic indicators that show the status of the PLC and the CPU. Such indicators include power OK, memory OK, and communications OK conditions.

- First, check that the PLC is receiving enough power from the transformer to supply all the loads. If the PLC is still not working, check for voltage supply drop in the control circuit or for blown fuses.
- If the PLC does not come up even with proper power, then the problem lies in the CPU. The diagnostic indicators on the front of the CPU will show a fault in either memory or communications. If one of these indicators is lit, the CPU may need to be replaced.

Safety Considerations

Actively thinking about the safety of yourself and others, as well as the condition of your equipment, is of primary importance.

When troubleshooting, pay careful attention to these general warnings:

Have all personnel remain clear of the controller and equipment when power is applied. The problem may be intermittent and sudden unexpected machine motion could result in injury.
Have someone ready to operate an emergency-stop switch in case it becomes necessary to shut off power to the controller equipment.
Never reach into a machine to actuate a switch since unexpected machine motion can occur and cause injury.
Remove all electrical power at the main power disconnect switches before checking electrical connections or inputs/outputs causing machine motion.
Never alter safety circuits to defeat their functions. Serious injury or machine damage could result.

Calling for assistance

If you need to contact manufacturer or local distributor for assistance, it is helpful to obtain the following (prior to calling):

 Processor type, series letter

 Processor LED status

 Processor error codes

 Hardware types in system (I/O modules, chassis)

 Revision of programming device (HHT or APS).

Self-Check 3	Written Test

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

Answer the following question as directed below

1. If testing of the PLC output voltage indicates that it is normal then the fault might be a wiring fault or a device fault.(True False)
2. Failure of an input LED to illuminate as required could be because
   - A. Input device is not correctly operating,
   - B. input device is not correctly powered,
   - C. Incorrect wiring connections to the input modulle, or LED or input module is defective.
   - D. All
3. .All I/O systems allow modules to be replaced while power is still applied.(True, False)
4. If the PLC does not come up even with proper power, then the problem lies in the CPU .(True, False)
5. LED indicators greatly assist the troubleshooting process. .(True, False)
6. The schedule for PLC preventive maintenance depends on the controller's environment. .(True, False)

. Answer the following question!

Note: Satisfactory rating 7and 12 points Unsatisfactory below 7and 12points

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

Score = ____________
Rating: _____________

Answer Sheet

Name: ___________________________ Date: _______________

Operation title: -Diagnosing and Troubleshoot faults in PLC

Purpose	**To acquire the trainees with diagnosing and troubleshoot PLC**
Equipment ,tools and materials	Supplies and equipment needed or useful for diagnosing and troubleshoot instrumentation and control Devices include these: • Siemens Logo PLC • Siemens software • screw driver • Diagonal side cutter • Pliers • Knife • Soldering iron • wrench • Digital Multi-tester • various instrument and control device
Conditions or situations for the operations	• All tools, equipment's and materials should be available on time when required. • Appropriate material, working area/ workshop to diagnosing and troubleshoot PLC

Procedures	13. Apply OH &S PPE 14. Identify instrumentation and control devices 15. Determine the Symptoms and analyze them. 16. State the symptoms as clearly and precisely as possible. Stating that a device does not work, while perhaps true, is not a clear, informative statement of symptoms 17. Localize to a functional module. Think, Look, and Test. 18. Isolate to a circuit. Think, Look, and Test. 19. Locate the specific component or problem. Think, Look, and Test. 1. Determine the cause of the failure. 2. Explain the type of faults you diagnosed 3. Replace or correct a defective component or problem and correct the causes of the failure. 4. Check for correct operation and calibration. 5. Complete the record keeping. 6. Review the entire troubleshooting and repair process. It is the best way to improve your troubleshooting skills.. 7. Complete and report fault diagnosis and rectification activities 8. Record the result
Precautions	• Care should be taken while connecting with electric power, assembling, fitting and adjusting instrumentation and control devices, PLC

	• Preparing materials, tools and equipment are according to inseminator command.
Quality criteria	• Did personal protective equipment worn diagnosing and troubleshoot PLC • Did trainees diagnose and troubleshoot of the PLC • Checks the circuit safely using proper instrument • Installs electrical wiring according to the job requirements

Diagnosing and troubleshoot faults in PLC

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

Instructions:

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

1.1. Diagnosing and troubleshoot faults in PLC

1.2. Prepare equipment and material for diagnosing and troubleshooting of faults in PLC

2. Request your teacher for evaluation and feedback

Information Sheet 4. Creating/Preparing External documentation and back-up programs

4.1 Creating/Preparing External documentation and back-up programs

System documentation

The documentation is the main guide used by the users and for troubleshooting and fault finding with PLCs.

The documentation for a PLC installation should include:

- A description of the plant.
- Specification of the control requirements.
- Details of the programmable logic controller.
- Electrical installation diagrams.
- Lists of all inputs and outputs connections.
- Application program with full commentary on what it is achieving.

- Software back-ups.
- Operating manual, including details of all start up and shut down procedures and alarms.

Self-Check 4	Written Test

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

Answer the following question as directed below

1. _________is the main guide used by the users and for troubleshooting and fault finding with PLCs.
2. The documentation for a PLC installation should include:

. Answer the following question!

Note: Satisfactory rating 1 and 1points Unsatisfactory below 1 and 1 points

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

Score = ___________
Rating: ____________

Answer Sheet

Name: _________________________ Date: _______________

operation title: - building a pneumatic circuit for a turning device-control by pilot valve

Purpose	to acquire the trainees with building a pneumatic circuit for a turning device-control by pilot valve
Equipment ,tools and materials	Supplies and equipment needed or useful for building a pneumatic circuit for a turning device-control by pilot valve include these: • Pneumatic trainer model • valve • screw driver • Diagonal side cutter • Pliers • Knife • drill • shaper • Digital Multi-tester • various instrument and control device • double acting cylinder

	• 3/2 push button valve • 3/2 roller valve • shuttle valve • 3/2 foot pedal actuated valve • 5/3 pneumatic actuated direction control valve • compressed air source and connecting piping
Conditions or situations for the operations	• All tools, equipment's and materials should be available on time when required. • Appropriate material, working area/ workshop to diagnosing and troubleshoot instrumentation and control devices
Procedures	20. Apply OH &S PPE 21. Identify instrumentation and control devices 22. Consider a simple operation where a double-acting cylinder is used to transfer parts from a magazine. 1. The cylinder is to be advanced either by operating a push button or by a foot pedal. 2. Once the cylinder is fully advanced, it is to be retracted to its initial position. 3. A 3/2-way roller lever valve is to be used to detect the full extension of the cylinder. 4. Record the result
Precautions	• Care should be taken while connecting with electric power, assembling, fitting and adjusting instrumentation and control

	devices • Preparing materials, tools and equipment are according to inseminator command.
Quality criteria	• Did personal protective equipment worn diagnosing and troubleshoot instrumentation and control Devices • Did trainees fitting and adjusting the component of the machine proper without leakage • Checks the circuit safely using proper instrument • Mounts devices according to the given drawing • Installs electrical wiring according to the job requirements

Building a pneumatic circuit for a turning device-control by pilot valve

LAP Test	Practical Demonstration

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

Instructions:

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

1.1. Prepare equipment and material for building a pneumatic circuit for a turning device-control by pilot valve

1.2. Building a pneumatic circuit for a turning device-control by pilot valve

2. Request your teacher for evaluation and feedback

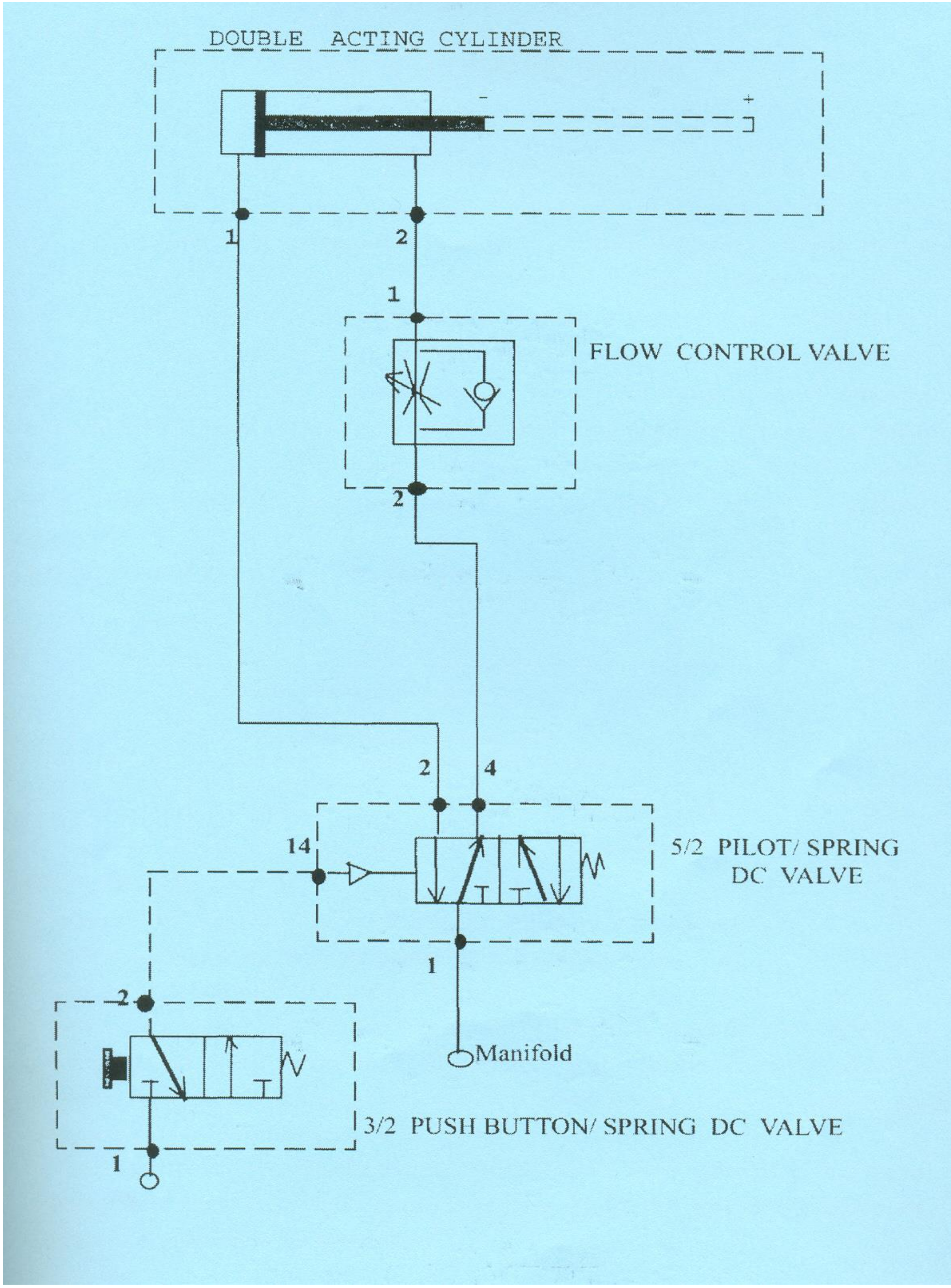


Figure 70: for: Operation Sheet-1- Turning Device

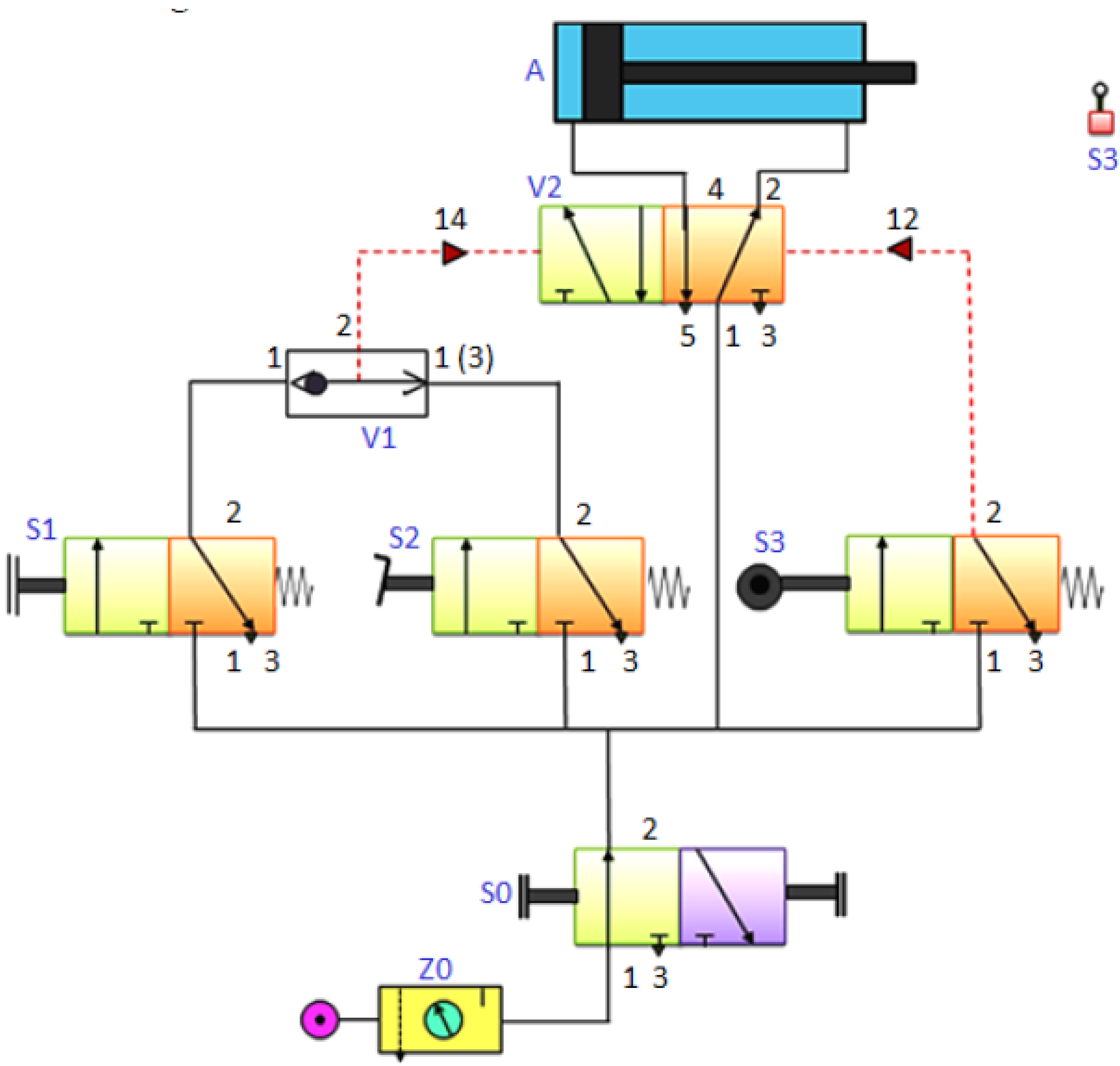


Fig 99: Operation Sheet-2- Double-acting cylinder used to transfer parts from a magazine

LG #29	LO #4- Clean-up

Instruction sheet

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

- Cleaning and clearing Work site
- Cleaning and storing tools and equipment

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:

- Cleaning and clearing Work site
- Cleaning and storing tools and equipment

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).

Information Sheet 1 Cleaning and clearing Work site

1.1 Cleaning and clearing Work site

1. Introduction

Clearing is the process of removing unwanted substances, such as dirt, infectious agents, and other impurities, from an object or environment. Cleaning occurs in many different contexts, and uses many different methods. Several occupations are devoted to cleaning. Housekeeping is not limited to keeping the place clean; it is also concerned with keeping equipment and materials in good repair and in their proper place. Good housekeeping is essential to preventing losses or injuries every injury caused by housekeeping can be prevented if everyone helps to keep the work area clean.

Work station is defined as an area, in an office, outfitted with equipment and furnishings for one or more workers.

It is necessary for a worker to prepare his work station and the pieces to be done but before doing so a worker should be well aware of the safety rules and regulations.

Efficient production and a good working environment are complementary.

1.1 Cleaning and clearing work site

The elimination of inefficiencies and accident hazards caused by unfavorable conditions in and about the workplace is essential in getting the job done properly and safely. The attention to these important details which may be overlooked when management's attention is concentrated upon such amenities as good cloakrooms, canteens, rest rooms, recreational facilities, etc. is widely referred to as "good housekeeping.

A clean, well-ordered, attractive work environment sets the tone of your establishment. It encourages tidy work habits in employees. It helps reduce fatigue. It promotes good worker-management relations. It also gives a lift to morale, which is reflected in the quality of production and overall efficiency. Good housekeeping is also a good advertisement for your company. Customers and clients have more confidence in an organization when they see work being carried out efficiently in clean, pleasant, well ordered surroundings.

Good housekeeping is a vital factor in preventing accidents. The great majority of all work accidents are caused during the handling of goods or materials, and by people falling, being hit by falling objects, or striking against objects in the workplace. All these causes can be reduced by good housekeeping practices in fact; good housekeeping is the only cure for hundreds of accidents that occur.

1.2 Clean-up procedure

1. Clean down all pieces of plant and equipment, and all tools. This might involve brushing, scraping or hosing.
2. . Check all parts for any damage. Place any damaged parts aside to be repaired or tagged and reported.
3. Sort and stack all parts neatly so they're easy to find when needed next.
4. Look over the entire area for any remaining parts, materials, tools, equipment

   or rubbish.

Self-Check 1	Written Test

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

Directions: For the following questions, say TRUE if the statement is

correct and FALSE if it is incorrect (wrong).

1. Efficient production and a good working environment are complementary. .
2. Good housekeeping is a vital factor in preventing accidents.
3. Good housekeeping is a good advertisement for any company.

. Answer the following question!

Note: Satisfactory rating 4and 6 points Unsatisfactory below4 and 6points

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

Score = ____________
Rating: _____________

Answer Sheet

Name: ___________________________ Date_______________

Information Sheet 2. Cleaning and storing tools and equipment

2.1 Cleaning and clearing Work site

The area where the hand tools and equipment have been left in the same condition they were in before the work began. Requirements related to this are part of various rules and Regulations, including local council building and development policies and environmental controls. Some of these vary depending on location. Check with a supervisor to find out what clean-up rules you need to follow on your worksite.

2.2 Cleaning and storing equipment to their proper places

All plant, tools and equipment need to be cleaned, inspected and stored neatly so that they're easy to identify when the next person needs them. Your supervisor is likely to have a set of standard work practices you can follow for this stage of work.

Tools and Equipment

Testing equipment should be tested regularly to ensure the level of protection required. Test instruments that are to be used or connected to electrical equipment should meet the following conditions:

- be suitable for the work in terms of their function, operating range and accuracy
- Be in good condition and working order, clean and have no cracked or broken insulation. Particular care must be taken regarding the condition of the insulation on leads, probes and clips of test equipment

- pose no danger of electrocution to workers or damage to the electrical equipment during testing
- have suitably insulated leads and connection probes that enable connection or contact with energized parts to be made with minimal risk to the electrical worker
- Provide suitable protection against hazards arising from over-voltages that may arise from or during the testing or measurement process.

Look after your tools and equipment so that they're ready for use the next time you need them. They need to be cleaned then stored correctly. Check the manufacturer's instructions for specific information regarding the cleaning requirements for each tool you use. Once tools are clean, remove any moisture by wiping them over with a clean, dry cloth then store them in a dry, secure place. This extends their working life and ensures that they'll work properly the next time you need them.

Self-Check 2	Written Test

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

Directions: For the following questions, say TRUE if the statement is correct and FALSE if it is incorrect (wrong).

1. Testing equipment should be tested regularly to ensure the level of protect on required
2. Adequate maintenance may lead to serious electrical risks.
3. Particular care must be taken regarding the condition of the insulation on leads of test equipment.

. Answer the following question!

Note: Satisfactory rating 6 and 11 points   Unsatisfactory below 6 and 11 points

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

Score = ___________
Rating: ____________

Answer Sheet

Name: _________________________   Date: _______________

Answer Key for self-check

Module Title: Operating a Butter Churning and Oil Production Process

LO #1- **Plan and prepare for installation**

:

Self-Check 1	**Written Test**

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

1. **True**
2. **False**
3. **True**

Self-Check 2	**Written Test**

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

1. **True**
2. **False**
3. **True**
4. **True**
5. **True**

Self-Check 3	**Written Test**

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

1. A
2. B
3. C

4. D
5. E
6. F

Self-Check -4	Written Test

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

1. **D**
2. **D**

1. **C**

Self-Check 5	Written Test

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

1. **B**
2. **A**
3. **D**
4. **C**

LO #2- Install/Test field and control devices	
Self-Check 1	**Written Test**

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

1. **True**
2. **True**
3. **False**
4. **False**

5. **True**

Self-Check 2	Written Test

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

1. TRUE
2. TRUE
3. TRUE
4. TRUE
5. TRUE

Self-Check 3	Written Test

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

1. **Installation testing**.

2. Installation testing

Self-Check 4	Written Test

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

1. To prepare the report, you will need to have information from the members of the project team on:

- completion of delegated tasks;

- completion of key stages;
- any work that is behind schedule (and why);
- any issues that need to be resolved (as soon as they arise);
- any difficulties anticipated in the near future.

2. The main categories of risk can be summarized as:

- physical loss of or damage to information, equipment or buildings as a result of an accident, fire or natural disasters;
- technical systems that do not work or do not work well enough to deliver the anticipated benefits;
- labor key people unable to contribute to the project because of, for example, illness, career change or industrial action;
- political/social for example withdrawal of support for the project as a result of change of government, a policy change by senior management, or protests from the community, the media, patients, service users or staff;
- liability legal action or the threat of it because some aspect of the project is considered to be illegal or because there may be compensation claims if something goes wrong.

3. Ask the following questions before any new equipment installation.

1. First, be sure to talk to your supplier's project manager before starting preparation for the installation.

2. Ask your supplier about electrical requirements and other necessities that need to be on-site for proper installation.

3. Where are drop sites for these items located?

4. Are there out-of-the-ordinary environmental conditions at the plant?

Self-Check 5	Written Test

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

1. True
2. True
3. True

LO #3 **Create/Modify, install and test basic PLC program**

Self-Check 1	Written Test

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

- TRUE
- TRUE
- TRUE

Self-Check 2	Written Test

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

. True

2. True

3. False

4. True

5. False

6. True

7.True

Self-Check 3	Written Test

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

.1. True

2. D

3. True

4. True

5. True

6. True

Self-Check 6	Written Test

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

3. Documentation
4. The documentation for a PLC installation should include:
   - A description of the plant.
   - Specification of the control requirements.
   - Details of the programmable logic controller.

- Electrical installation diagrams.
- Lists of all inputs and outputs connections.
- Application program with full commentary on what it is achieving.
- Software back-ups.
- Operating manual, including details of all start up and shut down procedures and alarms.

LO #4 Clean-up

Self-Check 1	**Written Test**

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

1. True
2. True
3. .True

Self-Check 2	**Written Test**

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

1. True
2. False
3. .True

:

Acknowledgement

We wish to extend thanks and appreciation to the many representatives of TVET instructors and respective industry experts who donated their time and expertise to the development of this TTLM.

We would like also to express our appreciation to the TVET instructors and respective industry experts of Regional TVET Bureaus, TVET College/ Institutes, BEAR II Project, Bishoftu Management Institute Center, UNESCO and Federal Technical and Vocational Education and Training Agency (FTVET) who made the development of this curriculum with required standards and quality possible.

This TTLM developed on December 2020 at Bishoftu Management Institute Center.

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4. Automating Manufacturing Systems with PLCs

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