**Programmable Logic Controllers (PLCs)**

Introduction

A PLC is a microprocessor based specialized computer with a programmable memory for storing instructions to implement specific functions such as logic, sequencing, timing, counting and arithmetic to control machine and processes.

Components

The main parts of PLC are central processing Unit (CPU), Input/output Module and program/ Monitor.

Block diagram
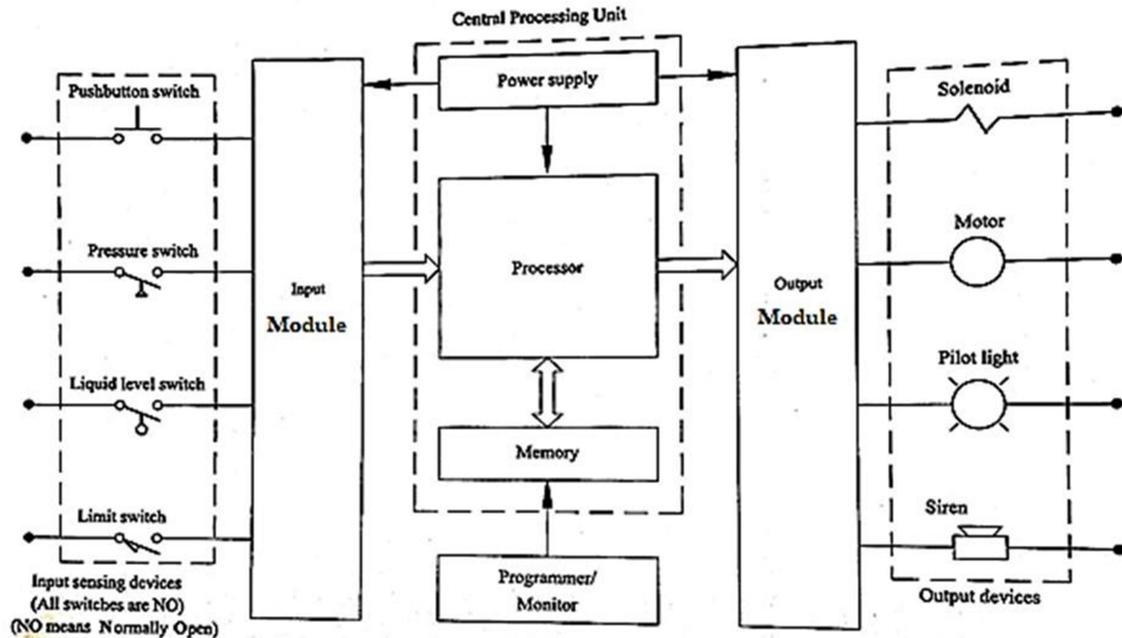
Description

Central Processing Unit (CPU)

The Central Processing Unit (CPU) Module is the brain of the PLC. It consists of processor and memory and Power Supply.

Processor:

The processor is the heart of CPU. The processor stores data in the memory. It is used to implement logical and mathematical operations. The processor reads input data from various sensing devices, executes the stored program from memory and sends appropriate output commands to control devices. It sends data out to external devices like output module. A Processor used in a PLC is 1-bit processor or word processor.

Memory:

The memory system is the area in the CPU where all the programs, are stored and executed by the processor to provide the desired control of field devices.

Power Supply:

The power supply provides power to memory system, processor and I/O Modules. It converts the higher level AC line Voltage to various operational DC values for electronic circuitry. It filters and regulates the DC voltages to ensure proper computer operations.

Input/ Output Module (I/O Module)

Input modules:

It senses the presence or absence of an input signal at each of its input devices like push buttons, limit switches. In digital input module, the input given to processor from input devices will be only 0(off) or 1(ON). In analog input module, variable input like real time machine temperature sensed by sensor will be given to processor.

Output Modules:

It receives the signal from the CPU and provides output to output devices like motors, motor starters, and solenoid valves. In digital output module, processor only switches ON or OFF the output devices. In analog module, processor controls the speed of output devices depending on the input given to processor.

Program/Monitor

The programming unit is used to enter the desired program into the memory of the processor. This program is entered using relay ladder logic, statements lists or control system flow charts. The programming unit allows the engineer/technicians to enter the edit the program to be executed. In its simplest form it can be hand-held device with membrane keypad for program entry and a display device for viewing program steps of functions.

Memory

Memories are made from Silicon. The function of memory is to store information.

ROM

A Read Only Memory is a Semiconductor memory device used to store the information permanently. The memory is read but not changed. It is a Non-Volatile memory.ie it can hold data even if power is turned off. Once the memory is programmed it can't be changed.

Types of ROM:
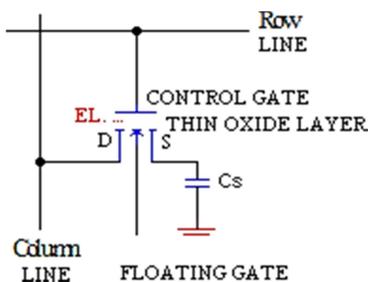 i)   PROM   ii) EPROM   iii) EEPROM

Programmable ROM: (PROM)

PROM is also known as One Time Programmable ROM (OTP). The PROM can be programmed once electrically by the user (ie) the data can be stored only once. It can't be reprogrammed.

Erasable ROM (EPROM):
The EPROMs can be programmed electrically by the user. It can be erased using UV light and reprogrammed.

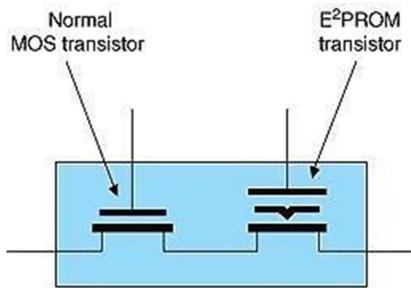**EPROM cell**   **Description**

EPROM has columns and rows and has two transistors. The two transistors are separated from each other by a thin oxide layer. One of the transistors is known as floating gate and the other is control gate. The floating gate is connected to Row through control gate.

Electrically Erasable PROM: (EEPROM)

EEPROM is also known as Electrically Alterable PROM (EAPROM). It is erased and programmed by using electrical pulses. It can be erased the information byte to byte.

EEPROM Cell

Description

The EEPROM transistor is similar to an EPROM transistor in that it contains a floating gate, but the insulating oxide layers surrounding this gate are very much thinner. The second transistor can be used to erase the cell electrically.

RAM

RAM is the memories that can be used for read & write operation. It is also known as Read Write Memory (RWM). RAM is a volatile memory so it loses the stored data when power is turned off.

Types of RAM:
i) Dynamic RAM   ii) Static RAM

Dynamic RAM:

Dynamic RAM uses capacitor for storing the data bit. Binary information is stored as charge. If charge is present at a capacitor, it represents logic 1 and in the absence of the charge, logic 0 is stored.

Static RAM:

Static RAM uses flip flop for storing the data bit. Data written into a flip-flop remains stored as long as power is maintained.

Input and Output Modules (Analog and Digital Modules)

Introduction

The I/O module provides an interface between switches, external devices and CPU.

Input Module

The module which interacts with the input signal is called as Input Module. It is required to connect input devices like different types of switches with Processor.

Input modules perform four tasks in the PLC control system
1) Sense when a signal is received from a sensor on the machine
2) Convert the input signal to the correct voltage level
3) Isolate the PLC from fluctuations in the input signal
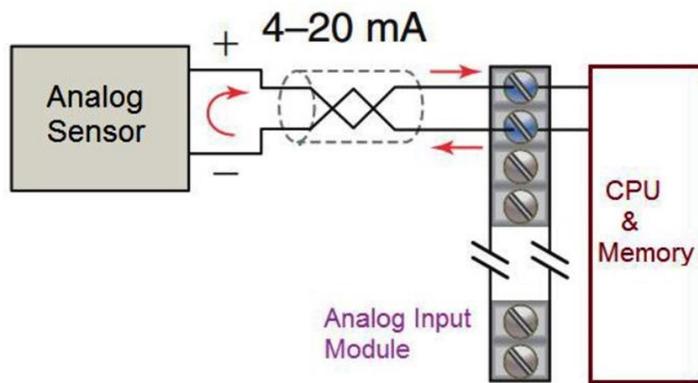4) Send a signal to the processor indicating which sensor sends the signal

Types

The two types of Input modules are

➡ Analog Input Module   ➡ Digital Input Module

Analog Input Module

An analog module is called a Continuous Module. Usually, the voltage or current is given to the input module in the form of an analog signal.

**Schematic diagram**

Description

The Analog input module is used to convert analog signal from analog devices, such as analog sensors, temperature probes, pressure indicator etc., to equivalent digital values using analog to digital converter. The analog input signal is usually a varying voltage in the range of 0-10V or current in the range of 4-20mA.

The transformed analog value is the digital equivalent of the analog input signal. Each converter value is stored in the memory in a digital form, typically as a 16-bit word for internal processing. They provide optical isolation for electrical noise protection.

Digital Input Module

The digital module is also called as Discrete Module. In this module, the signal works on the binary system i.e. only 0 or 1 value. Digital Input modules interface field input devices of on/off nature such as selector switches, pushbuttons and limit switches.

Schematic diagram
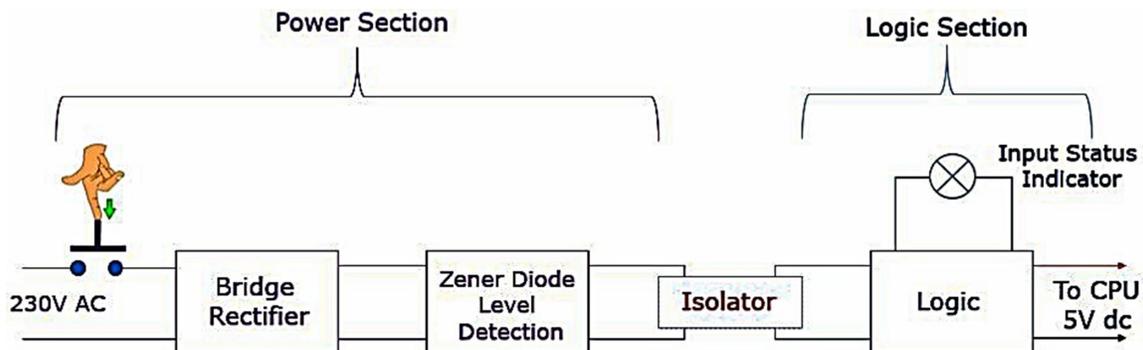
Description

It consists of two basic sections: the power section and logic section. The power and logic sections are coupled together by an isolator that electrically separates them.

Initially push button is closed. So, 220 V AC supply is given to the bridge circuit. A bridge rectifier is used to convert an AC signal into DC and Zener diode is used to provide a low voltage supply to a LED. The LED in the logic circuit is used to indicate the presence of a logic 1 signal in the logic section. The isolator circuit is made up of an opto- coupler. It is used to isolate the logic circuit from power circuit. DC signals from the opto-coupler are used by the logic section to pass the input signal to the CPU. Finally, a 5V DC supply is given to the processor.

Output Module

The module which interacts with the output signal is called as Output Module. The output module is required to connect output devices like electric applications with processor. An output module can be an electronic switch to which power is applied to control output devices.
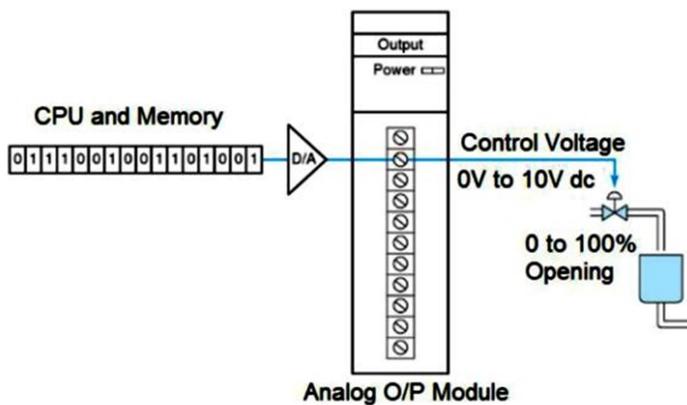
Types

The two types of output modules are

➡Analog Output Module ➡Digital Output Module

Analog Output Module

An analog module is called a Continuous Module. Analog output modules interface analog devices like Analog valves, Electric motor drives and pressure transducers with the output of CPU.

Schematic diagram

Description

The analog output modules converts processed digital values from the CPU into equivalent analog signals, typically in the range of 0 - 10V or 4 -20mA, to operate analog output devices using digital to analog converter. This analog output value is proportional to the digital numerical value received by the module. Analog output modules are selected to send out either a varying current or voltage signal. An analog output of 4 to 20mA sends to a variable speed drive. The drive will control the speed of a motor in proportion to the analog signal received from analog output module.

Digital output Module

The digital module is also called as Discrete Module. In this module, the signal works on the binary system i.e. only 0 or 1 value. A discrete output can either turns a device ON or OFF such as lights, LEDs, small motors, and relays.

Schematic diagram
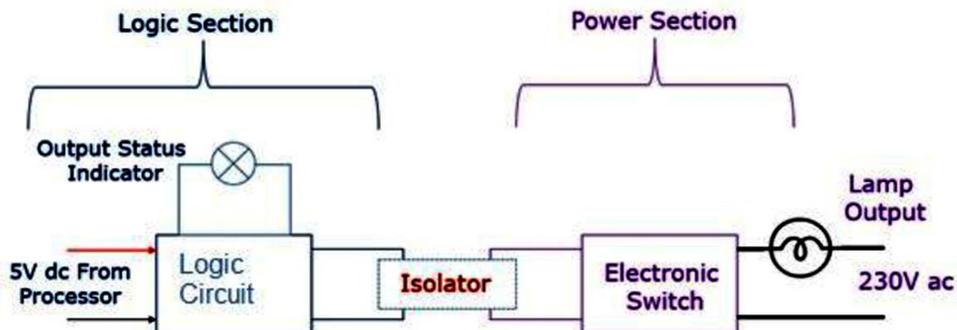
Description

It consists of two basic sections: the power section and logic section. The power and logic sections are coupled together by an isolator that electrically separates them.

When the program logic high signal is generated from the processor, the LED will turn ON. The LED is used to indicate the presence of a logic 1 signal. After the detection of signal from CPU, the logic section passes the signal to power section through an isolator. The isolator is made up of an opto coupler. Electronic switch in the Power section uses TRIAC to switch power. The switch is protected by a Snubber Circuit. When TRIAC in the switch is triggered, it switches into conduction and lamp is turned ON. Fuses are also required for the output module for protection.

Logic Functions

Logic

➡ Logic is the ability to make decisions.

➡ The binary concept has two predetermined states. For instance, a light can be on or off, a Switch open or closed, or a motor running or stopped.

➡ The binary 1 (or logic 1) is referred to as TRUE, ON, or HIGH, while binary 0 (or logic 0) is referred to as FALSE, OFF, or LOW.

➡ PLCs are based on three fundamental logic functions—AND, OR, and NOT.

AND gate

The AND gate has two or more inputs and one output signal. AND gate performs the logical operation is multiplication. The AND gate output is 1 only if all inputs are 1.
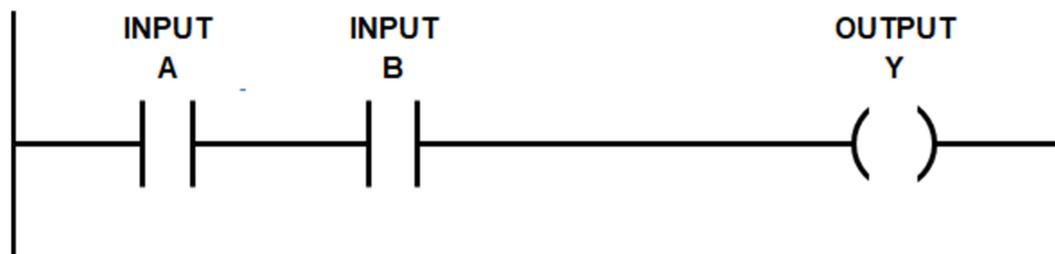
Logic Symbol   **Truth Table**
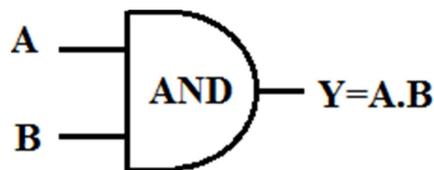
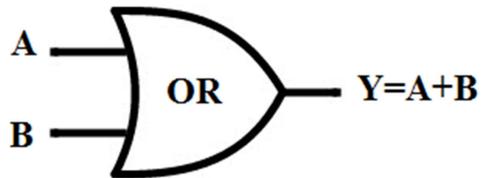| Input		Output
A	B	Y=A.B
0	0	0
0	1	0
1	0	0
1	1	1

PLC Ladder Logic

OR gate

The OR gate has two or more inputs and one output signal. OR gate performs the logical operation is addition. The OR gate output is 1 only if any one of the input is 1.
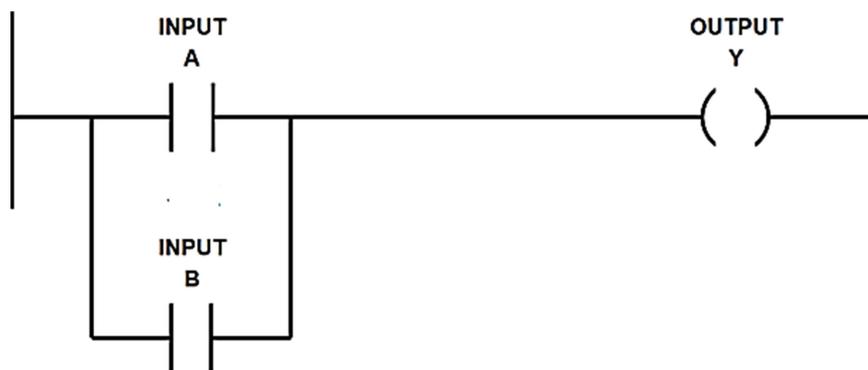
Logic Symbol   **Truth Table**

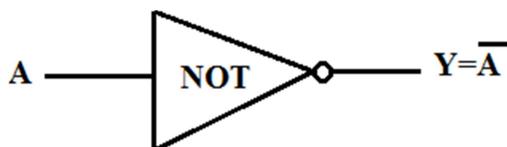| Input		Output
A	B	Y=A+B
0	0	0
0	1	1
1	0	1
1	1	1

PLC Ladder Logic

NOT gate

The NOT function can have only one input. The NOT output is 1 if the input is 0. The output is 0 if the input is 1. The result of the NOT operation is always the inverse of the input, and the NOT function is therefore called an inverter.
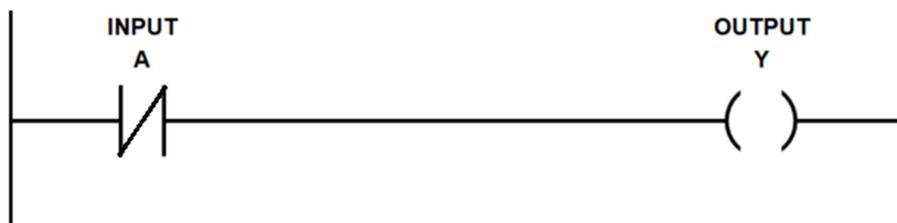
Logic Symbol   **Truth Table**

Input	Output
A	$Y=\overline{A}$
0	1
1	0

PLC Ladder Logic

Advantages & Disadvantages of PLCs

Advantages

➡ PLC increases the reliability, flexibility, and accuracy of the automation system.

➡ Cost of PLC is less

➡ PLC software has good capabilities and flexibility for programming.

➡ Programming used for PLC is easy to write and understand.

➡ PLC has the ability to easily communicate and connect with the computer.

➡ PLC does not take much space due to its smaller size

➡ The faults related to the complex hardware would be reduced due to the less wiring

➡ It gives supervisory control capability.

➡ The PLCs have less and simple wiring as compare to the other systems.

➡ It has remote control capability.

➡ It gives a fast response to the connected system.

➡ It has good computational function capabilities.

➡ PLC has a fast scan time.

➡ It requires very less operation time to perform any task.

➡ It can sustain in a robust environment with less maintenance

Disadvantages

➡ PLC requires too much work in connecting wires.

➡ It has a fixed circuit operation.

➡ PLCs manufacturers offer only closed-loop architecture.

➡ PLC is new technology so that should require training.

➡ There is a limitation of working of PLCs under high temperature, vibrations conditions.

➡ Some PLCs turn on when power is restored and may cause an accident.

➡ In PLC, there is difficulty with changes or replacement.

➡ PLC requires extra security equipment such as relays.

➡ PLC is designed by semiconductors, which depends on the thermal characteristics.

➡ It is always difficult to find an error and requires a skillful workforce.

➡ When we use PLC if a problem occurs then the hold-up time is indefinite usually long.

➡ Number of operational modules must be added to maximize flexibility and performance.

➡ PLC requires UPS (Uninterruptable Power Supply) for operational safety standards.

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Applications of PLCs

➡ **Manufacturing production**

   PLCs play an important role in manufacturing, acting as a central processor for all real- time decisions, despite fast technological developments

➡ **Automobile automation**

   PLC is used in Automobile automation processes to standardize the production process

➡ **Monitoring machine tool**

   A PLC serves as a machine tool to monitor inputs and outputs to make decisions based on the program stored in the PLC's memory. The use of PLCs helps to reduce human decision- making efforts to gain higher efficiency.

➡ **Steel industry**

   Every operation, such as managing temperature and pressure in boilers, raising electrodes, feeding oxygen lance for steel, controlling cooling bed, and so on, has relied heavily on PLC.

➡ **Robotic automation system**

   Robots are designed with powerful PLC software embedded into the robot controller.
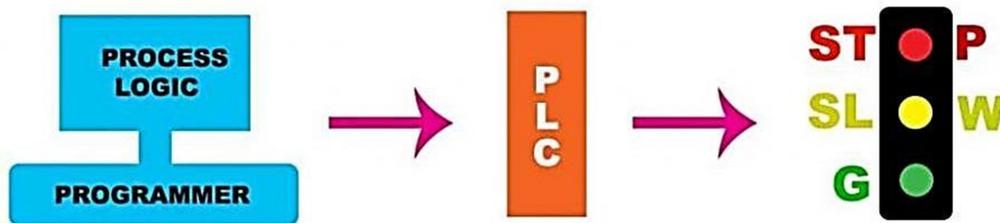
➡ **Glass industry**

   PLCs are used to control the material ratio and process flat glasses.

➡ **Food industry**

   The function of PLC in the food industry is filling machine control system.

➡ **Civil Applications**

   PLC is used in civil applications like washing machine, elevators working and traffic signals control.

➡ **Aerospace**

   PLC is used in aerospace for Water tank quenching system

➡ **.Travel industry**

   PLC is used to monitor the safety control system and to operate lifts and escalators in travel industry.

➡ **Paper industry**

   The function of a PLC in the paper industry is to automate processes at high speed to ensure efficiency.
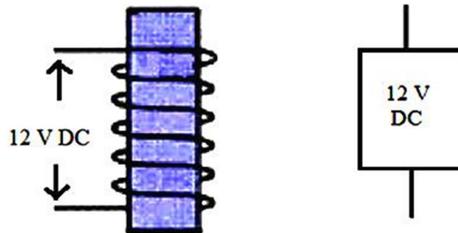
 Example: A PLC controls and supervises the creation of book pages or newspapers.

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Relays and their characteristics

Introduction

The Relay is an Electromagnetic switch that opens or closes the contacts to cause the operation of the other electric control.

Schematic Symbol:

Contacts:

i) Normally Open Contact (NO) ii) Normally Closed Contact (NC)

Types:

➡ Electromagnetic Relay   ➡ Solid State Relay

➡ Reed Relay   ➡ Time Delay Relay

Relay Characteristics:

The things that characterize a relay are the followings:

Coil voltage:- Coil voltage is the voltage that the coil can actuate the upper contact.

Coil current:- The coil will draw current when it is powered with the coil voltage is the coil current.

Off-voltage:- Off-voltage is the minimum voltage that   upper contact is pulled by electromagnet.
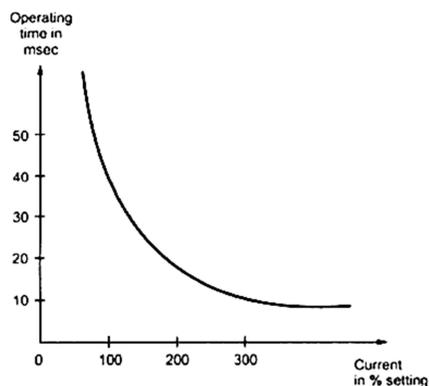
Power for the contacts-: It is the maximum power that the contacts can handle. **Operating temperature:-** The temperature that a relay can operate without problems **Switching frequency:-** The maximum make-break frequency

Current - time characteristics:

The Curve is drawn between Current and time.

Description:-

The Current - time characteristics of Relay is Hyperbolic. i.e Operating time decreases exponentially with increasing
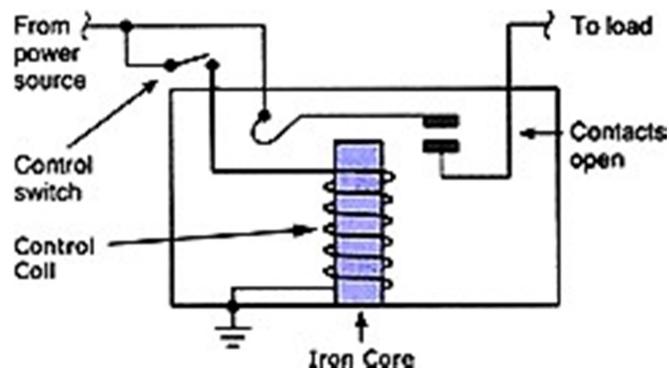
Electromagnetic Relays

Introduction

Electromagnetic relays works on the principle of electromagnetic attraction. It is a type of a magnetic switch which uses the magnet for creating a magnetic field. The magnetic field is used to open and close the switch for controlling the circuit.

Schematic Symbol
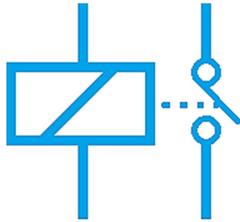
Circuit diagram

Construction

Electromagnetic Relay consists of a coil of wire surrounded by an iron core. The coil does not have magnetic property but can be converted into a magnet with the help of an electrical signal. So that only it acts as an electromagnet. Contacts are the conductive material that exists within the device whose physical contact opens or closes a circuit

Working:

The power source is given to the electromagnet through a control switch and through contacts to the load.

Case i) : Relay- Energized

When a power supply is applied to the control coil, current starts flowing through it and transforms the coil into an electromagnet. The electromagnet starts energizing and thus produces the magnetic field. Thus the upper contact arm starts to be attracted to the lower fixed arm and thus closes the contacts causing a short circuit for the power to the load.

Case ii) : Relay De-Energized

When a power supply is removed, then the coil current is off and the electromagnet starts de-energizing and thus reduces the magnetic field. Thus the upper contact returns to its original position. Hence the relay is de-energized.

Solid State Relays (SSR)

Introduction

A solid state relay (SSR) is an electronic switching device that switches on or off when an external voltage (AC or DC) is applied across its control terminals.

Schematic Symbol
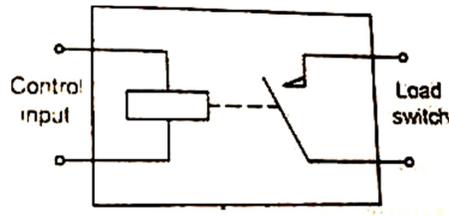
Description

The solid state relays do not have actual coils and contacts. Instead they are semiconductor switching devices such as bipolar transistors, MOSFETs, SCRs or TRIACS. The solid state relay has no moving parts, it is resistant to shock and vibration and it is sealed against dirt and moisture. In this circuit a light beam is used as the control medium, so voltage spikes or electrical noise could not be produced.

Circuit diagram

Construction

The input circuit consists of a LED which is triggered by the input voltage. Then, there is isolation between input and output circuits. The output circuit consists of a photo-coupler for capturing the light and converting it into electrical energy for the load drive circuit. The Load drive circuit consisting of Triac, diodes, transistors, or thyristors.

Working

When the power supply is applied to the input circuit, current flows through LED which emits light from it. The photo-coupler detects it and converts it into an electrical voltage which is then fed to the load drive circuit, for controlling the final output voltage to the load. When the input voltage turns off, the load too turns off. Due to the use of Opto-coupling technology, the switching is swift, sensitive, and has high insulation levels. The output voltage can be digital or analog, depending upon the input circuit and load drive circuit used. Solid state relays can be used to control AC and DC loads. It is more reliable and has a longer life compared to electromagnetic relays.

Reed Relays

Introduction

A reed relay is a small electromagnetic switching device that integrates a coil around one or more reed switches. The energized coil creates the magnetic field used to control the switching operation."
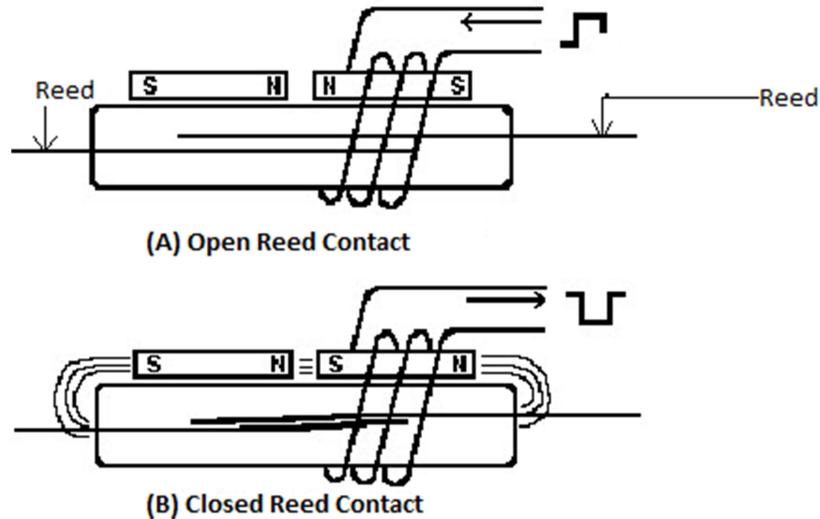
Circuit diagram
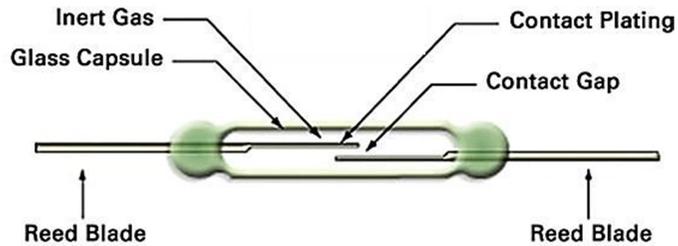
Construction

The reed relay consists of a pair of reed blades which are made with ferromagnetic material that is sealed within a glass envelope. This glass envelope of the relay is filled with dry inert gas to avoid contact oxidation. The reed blade acts as both an armature and a contact.

Working

Description

When the voltage is applied to the coil, current starts flowing through it and transforms the coil into an electromagnet. After that, the current through the coil generates a magnetic field so that reeds move towards each one and gets closed contact. So that switching operation is performed. Lastly, detaching the voltage supply from the coil will open the contact of the relay.

Based on dimensions, relays are differentiated as micro miniature, sub miniature and miniature relays. Also, based on the construction, these relays are classified as hermetic, sealed and open type relays. Furthermore, depending on the load operating range, relays are of micro, low, intermediate and high power types.

Time Delay Relay

Introduction

Time delay relays are relays with a time delay function built in.

Principle

Time delay relay provides a change of state of the contacts that are controlled by the energizing or de-energizing of the timer.
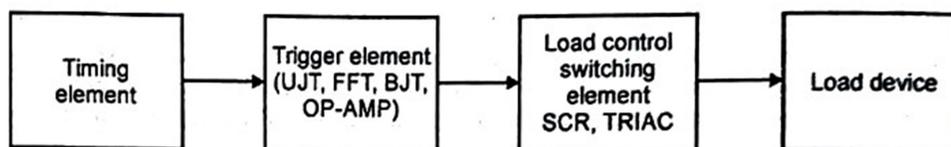
Types

➡ **On delay relay** –The on-delay relay is referred to as a DOE or Delay On Energize.

➡ **Off delay relay** - Off-delay relays are referred to as DODE or Delay On De-energize.

Electronic Time Delay Relay

Electronic Time delay relays are used in all applications where control of very short intervals of time and great flexibility of control is required
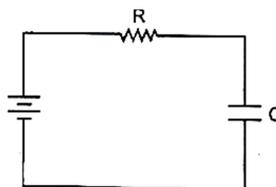
Block diagram

Description

Electronic Timer consists of Timing element, Triggering element, Switching element and Load device.

Timing element

The Timing element may be RC element and Digital element. The RC element produces time delay by the charge and discharge action of a capacitor through a resistor

      RC element
      Circuit
      diagram

The digital element produces pulses by an Oscillator or Pulse generator. The output of digital element is applied to the triggering device which is in turn used to control the Load control switching element and finally actuate the load.

Trigger Element

The trigger element is in the form of an active device which responds the output of timing element in an electronic timer. These active devices may be BJTs, FETs, BJTs, Op-amp etc., This trigger element amplifies the timing element signal.

Load Control Switching element

Load control switching element is a direct load energizing device which may be BJT, Triac, or SCR. Load control switching elements are turned on and off by using pulses from trigger element. The Load device is energised when the trigger signal is applied to the load control switching element.