CHAPTER 4

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The universe of discourse includes a lot of what can be described by two states (0,1). Read/write, start/stop, open/close, key/lock, forward/backward, up/down, left/right, release/block, enter/exit, clockwise/counterclockwise, on/off, high/low, full/empty, shine/dark, are all examples of two state expressions used to command two values actions or express the state of binary entities. These are the words needed in the construction of many process control algorithms. But as linguistic words neither the machinery nor the process controllers can understand. So to create an automated environment with full understanding between the human being, machinery, and process controllers a certain type of translation or interfacing should be sandwiched between the different entities. The binary state input devices (sensors) are the translators that inform the controller the states of the process whereas the binary output devices (actuators) play the translation role between the controllers and the machinery.

4.1: Sensors

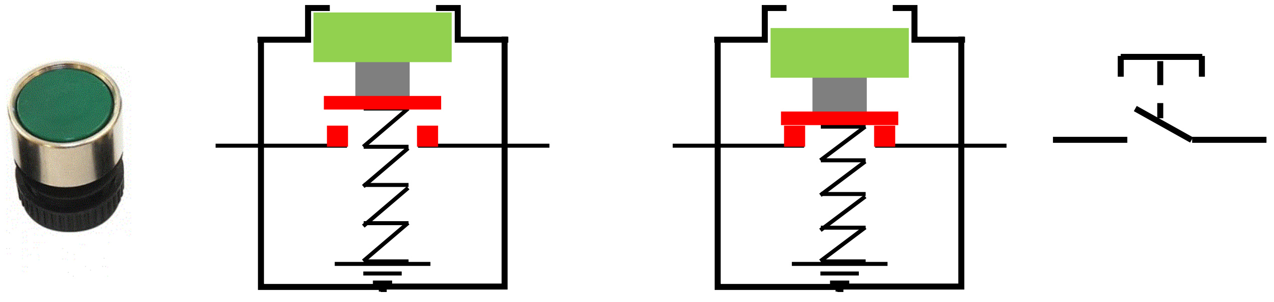
Sensors are input type devices have the ability to represent the value or state of a chosen parameter in a form suitable for decision making in programmable controllers. Binary sensors set includes many different types of switches (too many to cover). Hand operated switches, limit switches, inductive proximity switches, capacitive proximity switches, photo electric switches, magnetic switches, temperature actuated switches, pressure actuated switches, float switches, mercury switches, and shaft encoders are examples of the sensors set items.

4.1.1 :Hand Actuated Switches.

Human operator actuated switches share the same opening and closing functions but they differ in their shapes and activation / inactivation mechanism. The shape and activation / inactivation determine the application area. From these points of view, these switches can be classified into:

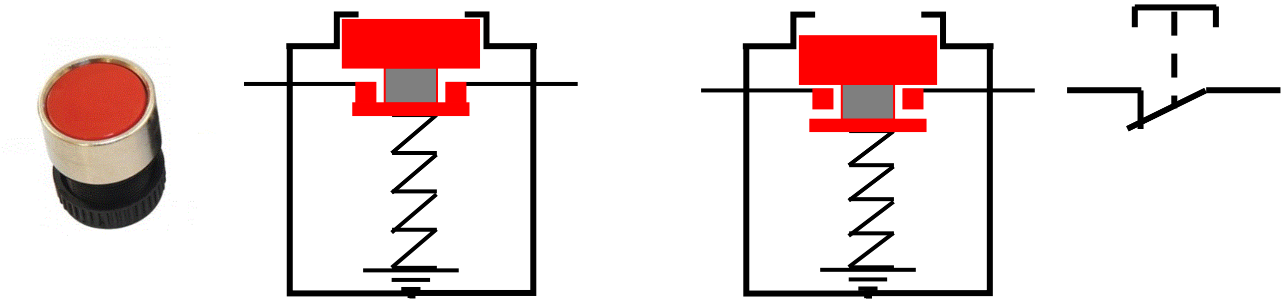
Shrouded Actuator Pushbuttons

These are finger tip actuated pushbuttons. They have an activation area surrounded or shrouded by hard sleeve to prevent unintended depressing of the button. The depressing is only possible by an object smaller than the sleeve. With finger tip it is possible to access the activation area but with hand palm, the sleeve blocks the entrance and no activation can take place. There are two types of these pushbuttons, the **black or green colored normally open** pushbutton and the **red colored normally closed** one. For both of them, the activation is done by depressing the actuator against the internal spring whereas inactivation occurs when removing the depressing object and allowing the spring to lift up the actuator. For the normally open one the activation bridges the button’s two terminals where as the inactivation isolates these two terminals creating an open circuit between them. In the case of normally closed one the activation does the reverse, it pushes away the metallic conducting bar creating an open circuit between the button's terminals and the inactivation returns the bar to its initial position and this in turn leads to bridge the button terminal again. Figs. 4.1and 4.2 present the real pictures of these pushbuttons, the schematic diagram of their internal configuration under pressed and released situations, and their circuit symbols respectively.



(a) (b) (c) (d)

Fig. 4.1: Shrouded actuator ON pushbuttons**. (a) :** Real picture . (b): Behavior under normal condition . (c): Behavior under pressed condition (d) : Circuit symbol

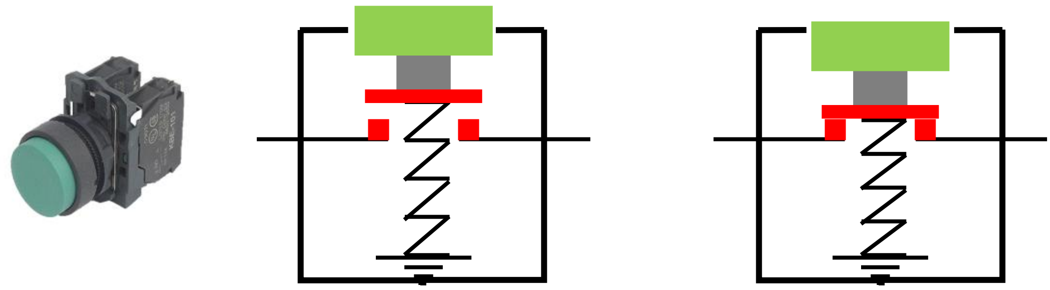


(a) (b) (c) (d)

Fig. 4.2: Shrouded actuator OFF pushbuttons**. (a) :** Real picture . (b): Behavior under normal condition . (c): Behavior under pressed condition. (d) : Circuit symbol

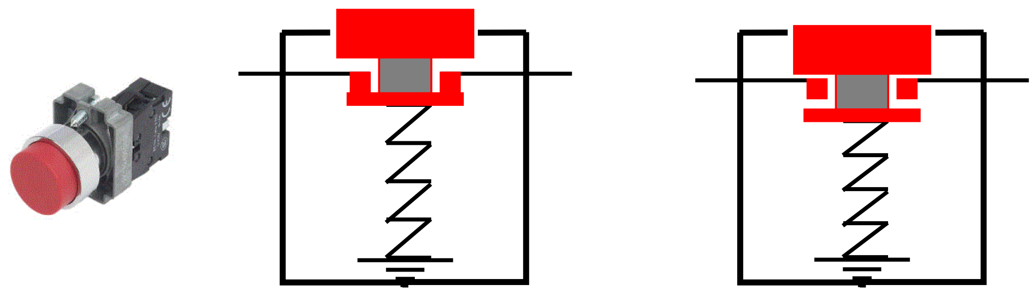
Extended Actuator Pushbuttons

These are similar in operation to their predecessors and share the same circuit samples but differ in their actuator shapes. Here the activation area is extended beyond the sleeve and this lead to an easy activation. They can be activated by objects smaller than their actuators like finger tip and also by object larger than their actuators like hand palm or more than one finger. Figs 4.3 and 4.4 display the external appearance of this type of pushbutton along with the operational behavior under pressed and released situations.



(a) (b) (c)

Fig. 4.3: Extended actuator ON pushbuttons**. (a) :** Real picture . (b): Behavior under normal condition . (c): Behavior under pressed condition

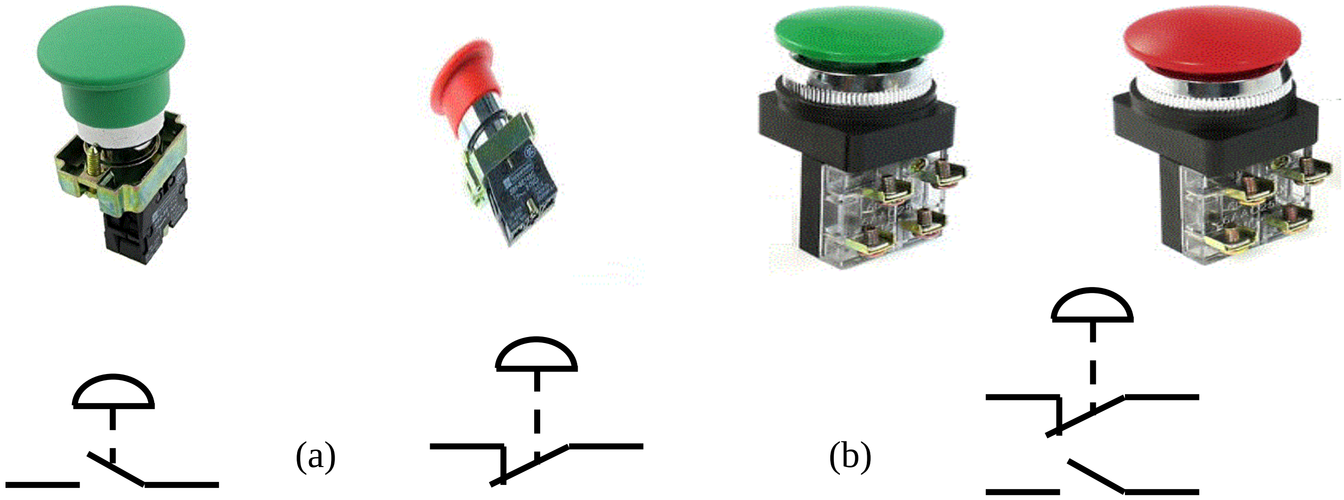


(a) (b) (c)

Fig. 4.4: Extended actuator OFF pushbuttons**. (a) :** Real picture . (b): Behavior under normal condition . (c): Behavior under pressed condition

Palm Actuator Pushbuttons

The palm actuated ON/OFF switches or simply mushroom switches have mushroom head like actuating shapes and internal springs to return them to their normal situations after lifting the depressing objects. Their mushroom head activation area is wide enough and smooth to be easily pressed by the operator. The operators can activates them comfortably by their palms. Usually they are used for making or breaking electrical circuit for short time periods. In general, their structure is suitable for ON/OFF applications that occur tenth times per day. Fig4.5 shows the single circuit and double circuit versions of these types of push buttons along with their circuit symbols.

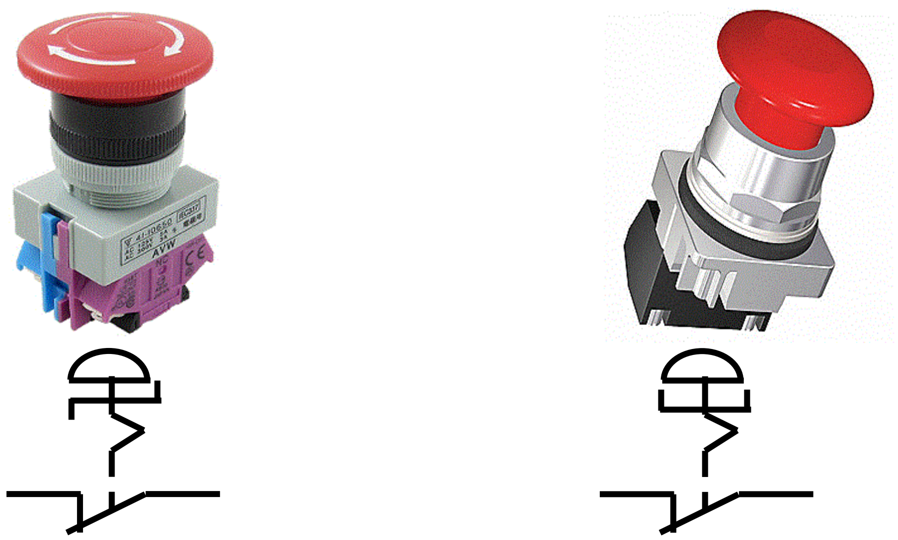


(a) (b)

Fig.4.5: Palm actuated pushbuttons. (a) : Single circuit type. (b): Double circuits type

Emergency Stop Pushbuttons

The emergency stop push buttons adopt the mushroom or palm type actuators to enable their users to activate them easily and quickly using any part of their bodies they can use at the time they need to activate these buttons. Always the mushroom type buttons used for emergency stop purposes are red colored and provided with detention or position maintaining mechanism to keep the switch in the active state (after being depressed) until later released by the operator by pulling its actuator up or rotating it in a specific direction marked on the activation face. Fig. 4.6 display samples of these emergency stop push buttons



(a) (b)

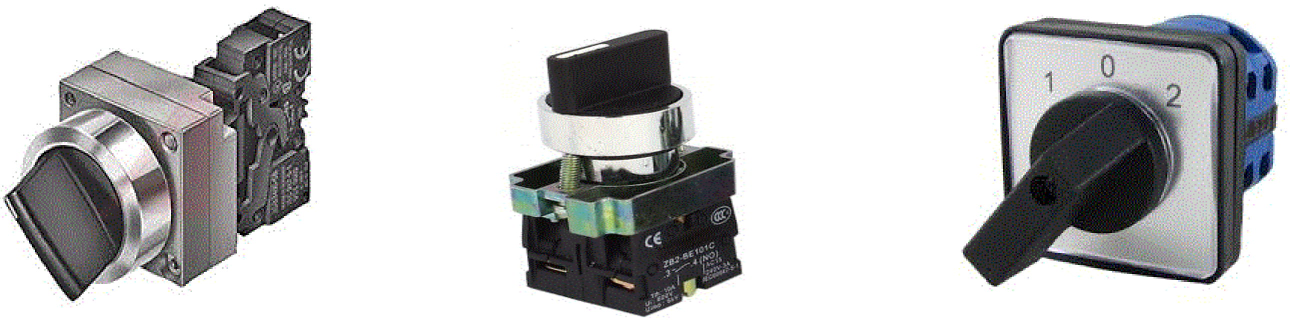
Fig.4.6:Emergency stop pushbuttons. (a): Rotate to release. (b): Pull up to release.

Two and Three Selector Switches

These hand actuated switches are also called rotary switches because their operational states depend upon the direction at which their lever are rotated. Some of these switches take one of two positions where as the others can be turned right, center, or left to open or close the electric contacts.

The first two position category is subdivided into two sub categories, one with one set of contacts and the other with two sets of contacts. The one with one set of contacts (Fig.7-a) behave either as short circuit through bridging its set's two contacts or as an open circuit through breaking the continuity between its set's two contacts. The one with two sets of contacts(Fig.7-b) has four connection points, two for the first contact set and two for the second contact set. As stated earlier, this switch toggles between one of two position. In the first position, one of the sets say "A" is forced to closes its two contacts to create short circuit and the second say "B" is forced to open its two contacts to create open circuit

The three positions category one (Fig. 7-c) has two contact sets and can be positioned in one of three positions left position, middle position, and right position. Here in the left position one of contact sets say "A" is opened and the second one say "B" is closed, in the middle position both A and B are opened, and in the right position A is opened and B is closed.



(a) (b) (c)

Fig.4.7: Samples of Selector switches.

4.1.2 : Mechanical Limit Switches.

Mechanical Limit switches are contact sensing devices used to detect the arrival or departure of relatively low speed moving objects in industrial applications. They are called so because when an object makes contact with the actuator of the switch , it eventually moves the operating mechanism to the limit where the switch electrical contacts change their states, the normally closed one becomes open and the normally open one becomes closed. Most of the mechanical limit switches consist of four items. These are:

- The actuator : It is that part of the switch which comes in contact with the moving object.
- Operating head : The operating head which is attached to the actuator allows the rotary, linear, or perpendicular movement to open and close the switch's contacts.
- Electrical Contacts and their terminals : Usually, the mechanical limit switches are provided by two sets of contacts. One set is of normally open contact type, and the other of normally closed contact type.
- The container : It is also called the switch body and it is where the contacts and their connecting terminals are mounted.

Broadly, mechanical limit switches are classified into lever type actuator and plunger type actuator. Fig.4.8 introduces samples of these two types.

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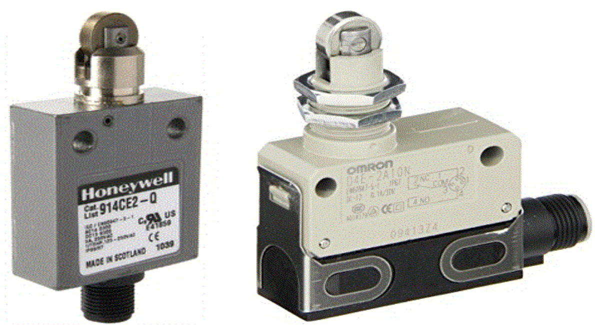
(a): Lever type sample



(a): Plunger type samples sample

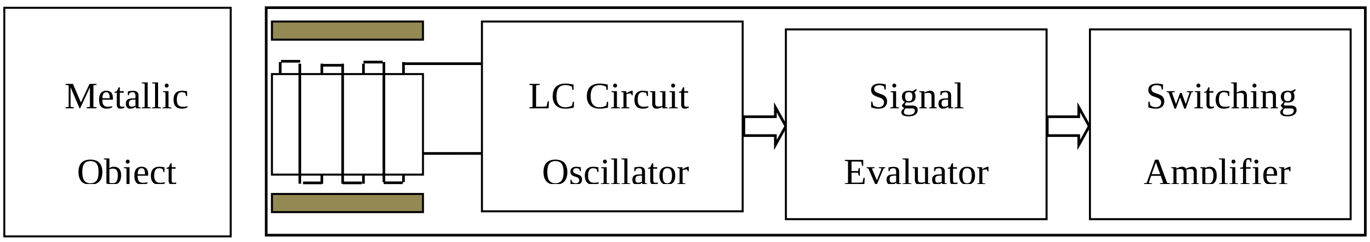
Fig.4.8: Samples of Limit Switches

4.1.3: Proximity Sensors.

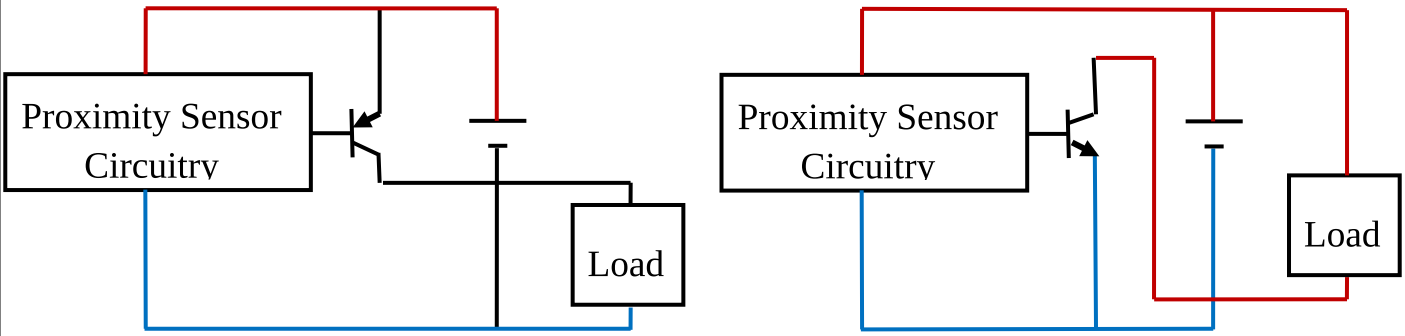
Proximity sensors are solid state electronic devices used to detect the presence or absence of an object without any real contact. They are activated/deactivated depending upon the nearness or closeness of the object being detected to the sensor face. There are four fundamental types of proximity sensors, the inductive proximity sensor, the capacitive proximity sensor, the photoelectric proximity sensor, and the ultrasonic proximity sensor. All these solid state devices are well protected against vibration, liquids, and corrosive agents in the industrial environment.

Inductive Proximity sensors

As their names imply, inductive proximity sensors are used to detect the presence or absence of metallic objects. The sensor as a package consists of LC oscillator, signal evaluator, and switching amplifier (see figure 4.9a). The operating principle is that when a metallic object comes close to the changing magnetic field created by the LC oscillator, eddy current will flow in the coming object causing an ohmic power loss. This power loss loads the oscillator. As the object moves nearer, the loading effect increases causing more reduction in the oscillator output. When the oscillator output reduction drops below the threshold level, the signal evaluation circuit triggers the switching output amplifier to change the binary state of the sensor. The label assigned to the sensor depends upon the switching amplifier output transistor. If the output transistor is PNP type, the sensor is called PNP or current-sourcing sensor (figure 4.9b). If it is NPN transistor, the sensor takes the label of current-sinking (figure 4.9c).



(a)



(b) (c)

Fig.4.9: Inductive Proximity Sensor.

Capacitive Proximity sensors

Capacitive proximity sensors are similar to inductive proximity sensors except that in capacitive type sensors the target material varies the capacitance of the RC oscillator whereas in the inductive sensor metallic target varies the inductance of the LC oscillator. Here the sensor package consists of

- An RC oscillating circuit for which the capacitor plates are part of the sensor itself (Fig. 4.10a) or the capacitor plates are distributed between one plate at the sensor face and the other is the earthed fixture (earthed machine cover or mounting bracket) to which the sensor is attached (Fig.10b).

- Capacitance change evaluation circuit: The capacitance of any plate type capacitor is function of the area of the plates, the distance separating the plates, and the permittivity of the dielectric sandwiched between the plates($C= \varepsilon_o \varepsilon_r A/d$). In general in this type of sensor, the plates area is fixed so the only parameters that may change the capacitance are the permittivity (ε_r) and separation distance (d). So any object that affect any one of these parameters will causes change in oscillator capacitance. The capacitance increases as the permittivity increases or the separation distance decreases. The capacitance decreases as the permittivity decreases or the separation distance increases.

- Switching amplifier : when the change in the capacitance comes above certain value, the evaluation circuit turns the output power transistor ON to connect the load either to the positive terminal of the dc supply in case of PNP type sensor (Fig.4.10c) or connecting the load to the negative terminal of the dc supply in case of NPN type sensor (Fig.4.10d). When the capacitance change drops below a threshold limit, the switching amplifier is turned OFF.

There are two types of capacitive sensors . These are the:

- dielectric type in which the capacitor plates are built in parts of the sensor. Here the target object only affect the permittivity parameter because both the area and the separation parameters are fixed. These types can be used for conductive and non conductive materials.

- Conductive type in which the sensor contributes only in one plate and the other belong to the metallic structure to which the sensor is attached, here the target object is of conducting nature (like metal, salt water, blood, acids, etc.) and it affects the separation distance .

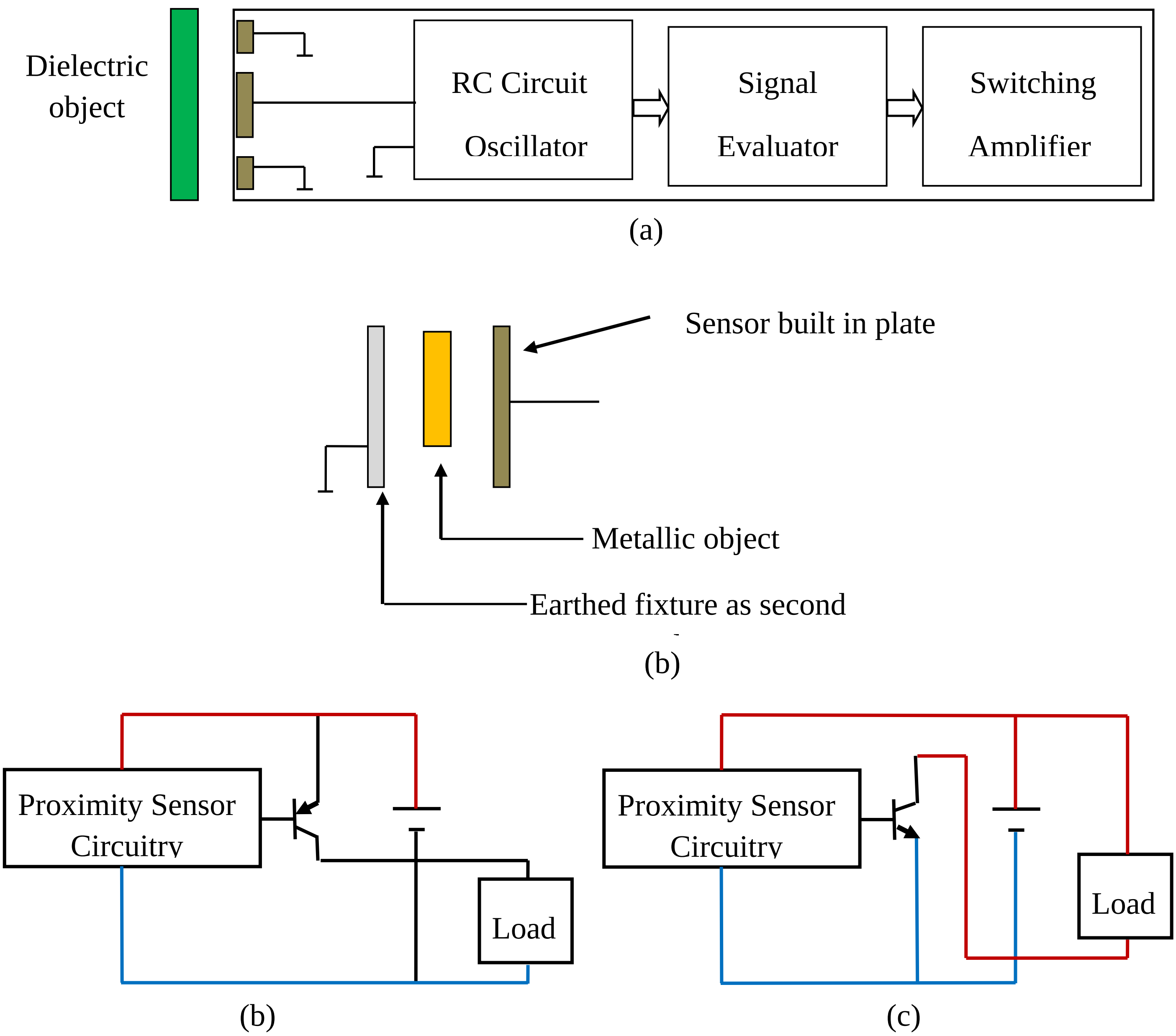


Fig.4.10: Capacitive Proximity Sensor.

Photoelectric Proximity sensors

Photoelectric proximity sensors are also another type of position sensors. They are used to sense the presence or absence of an object at predetermined positional point. They use light-emitting diodes to generate modulated light waves, phototransistors or photodiodes to detect the transmitted or reflected light waves, and switching electronic circuits to manipulate and evaluate the detected signal to decide whether to switch ON or switch OFF the burden connected to the sensors output. The light transmitter and receiver are positioned in such a way that the presence of the object under monitoring either blocks or reflects the emitted light beam. Fundamentally there are three types of optical sensors. These are the thru-beam optical sensor, the retro-reflective optical sensor, and the diffuse-reflective optical sensor.

Thru-Beam optical sensor

The transmitter and receiver of the thru-beam sensor are housed in different cases that are separated from each other (figure 4.11). Both the transmitter and receiver are provided with focusing lenses and are aligned in such a way that the greatest amount of pulsed light reaches the receiving unit. The transmitter emits light pulses to the receiver. When the light pulses are interrupted by the virtue of presence of opaque or reflective object, the switching action in the receiving unit is fired.

When using this type of sensor the following should be observed:

- It cannot be used to detect transparent objects.
- Vibration may create alignment problems and causes malfunction.
- The target size should be greater or equal to the lenses diameter.
- The maximum sensing distant is module dependent but it may reach to meters.

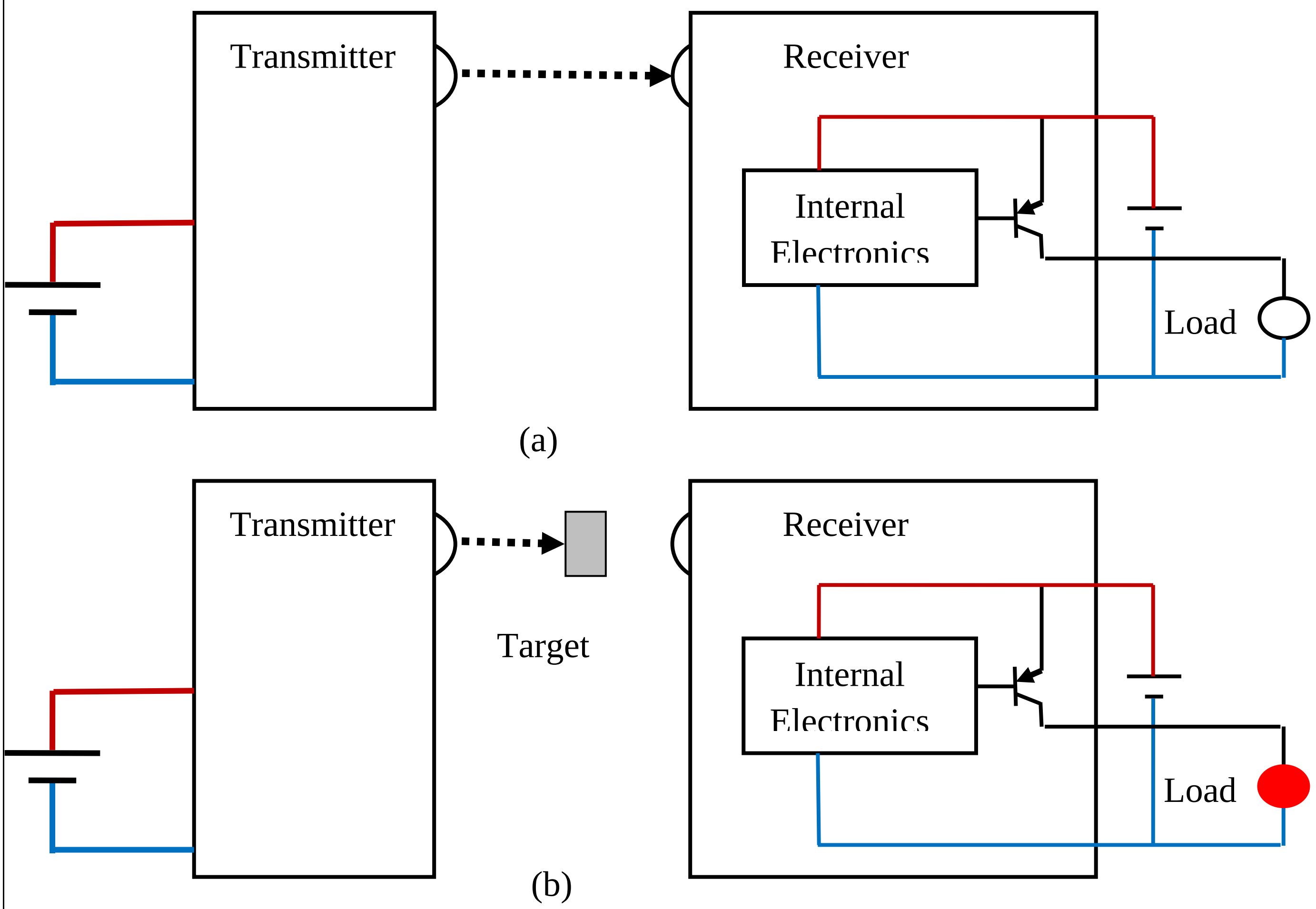


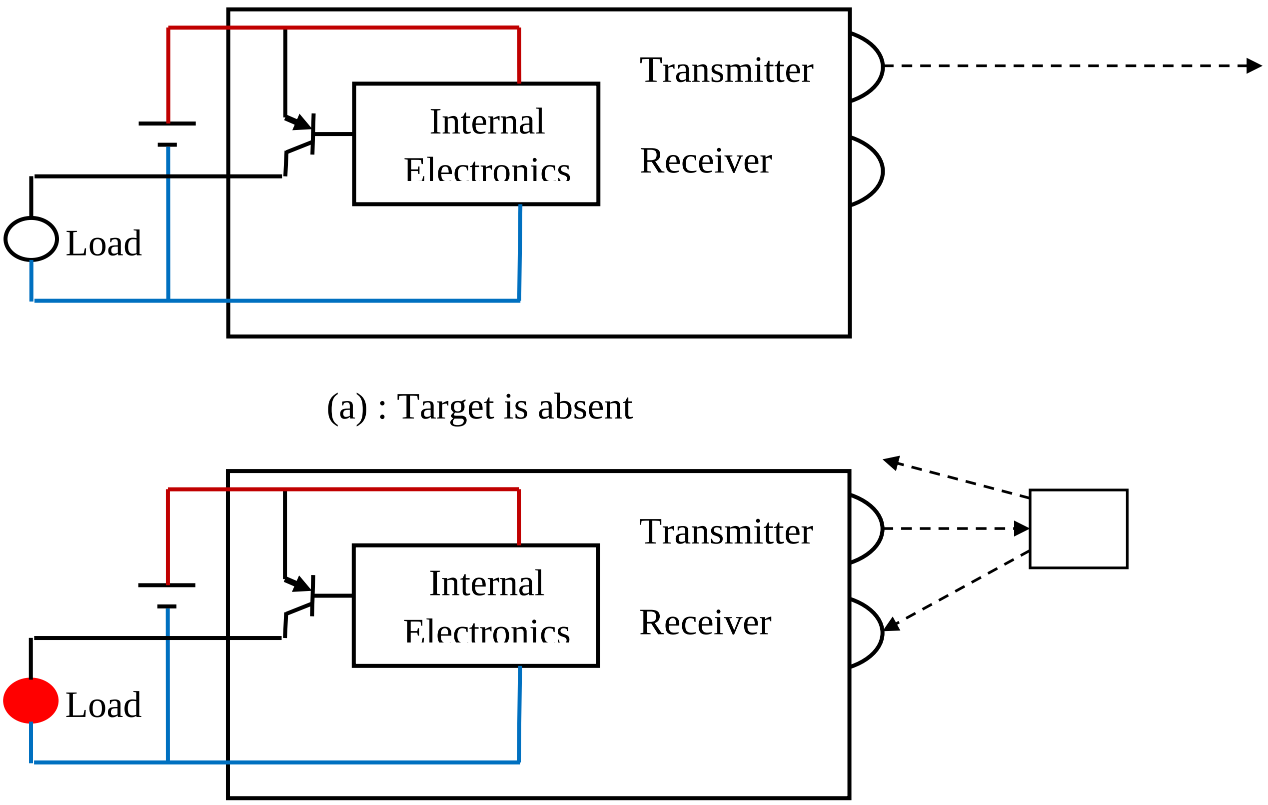
Fig.4.11: PNP Type Thru-Beam Optical Sensor. (a): No target. (b): Under presence of target

Diffuse-reflective optical sensor

In diffuse-reflective optical sensor, the emitter and receiver are located in single housing and the target itself is responsible for reflecting the light beam back to the sensing unit. Here the emitter should be placed perpendicular to the target (Fg.4.12), whereas the receiver is positioned at some angle to be able to receive the reflected light. Target presence reflects the transmitted light signal causing the triggering of the switching function. Target absence allows the light beam to travel far from the receiver and generates no switching signal.

When using this type of sensor the following should be observed:

- It cannot be used to detect transparent objects or objects with low reflectivity..
- It does not work if the background has lighter color than the object.
- The shape, the color of the object, and its background have an effect on how well it works. .
- The maximum sensing distant is small (within one meter).



(a) : Target is absent

(b) : Target is present

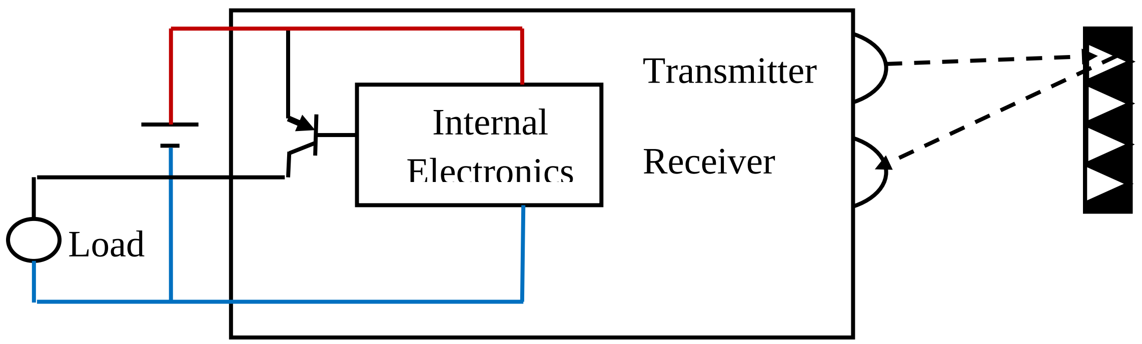
Fig.4.12: PNP Type Diffuse-Reflective Optical Sensor.

Retro-reflective optical sensor

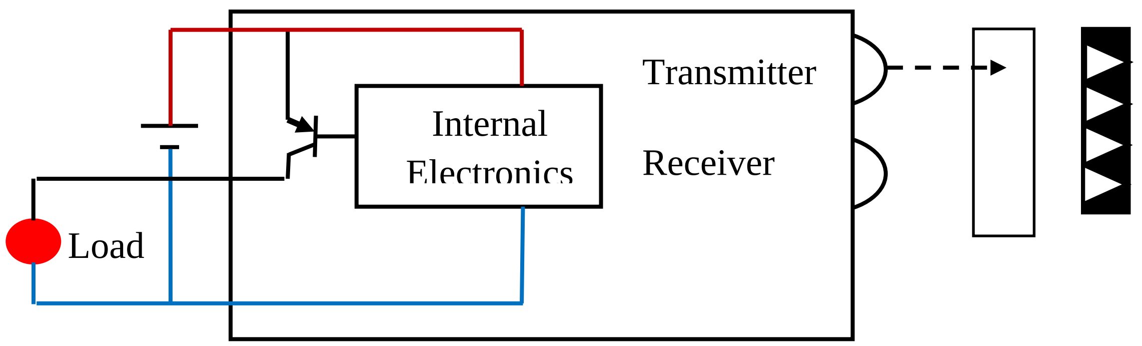
the retro-reflective sensor has both the emitter and receiver housed in single housing like the diffuse-reflective type. As it is clear from Fig.413, it has a reflecting item to reflect the light beam toward the receiver . The target presence blocks the light being received and fires the switching function. This type of sensors does not work well with glossy and reflective objects. To overcome this problem with glossy and reflective objects that reflect the light as if they were a reflectors, a linear polarizing filters are located in front of the transmitter and the receiver. The polarization planes of these filters are perpendicular to each other. With this modified structure, only light beams passing through the transmitter polarization filter, reflector, and the receiver polarization filter can reach the receiver unhindered.

- When using this type of sensor the following should be observed:

- The detecting distance is large and reaches 20 meters.



(a) : Target is absent



(b) : Target is present

Fig.4.13: PNP Type Retro-Reflective Optical Sensor.

4.1.4 Reed Switch

The word "reed" refers to a piece of thin and upright cane and it also refers to electrical contact used in magnetically operated switch. Here both meaning are of key importance, the first refers to springy feature and the second to conductive feature and these are what the reed switch contacts must be characterized with. The reed switch consists of two strips of springy ferromagnetic materials (e.g. iron-nickel) with their contacting ends coated with plating material (e.g. rhodium). These strips are sealed in inert gas filled glass or plastic capsule and are available in different sizes and shapes (Fig.4.14).

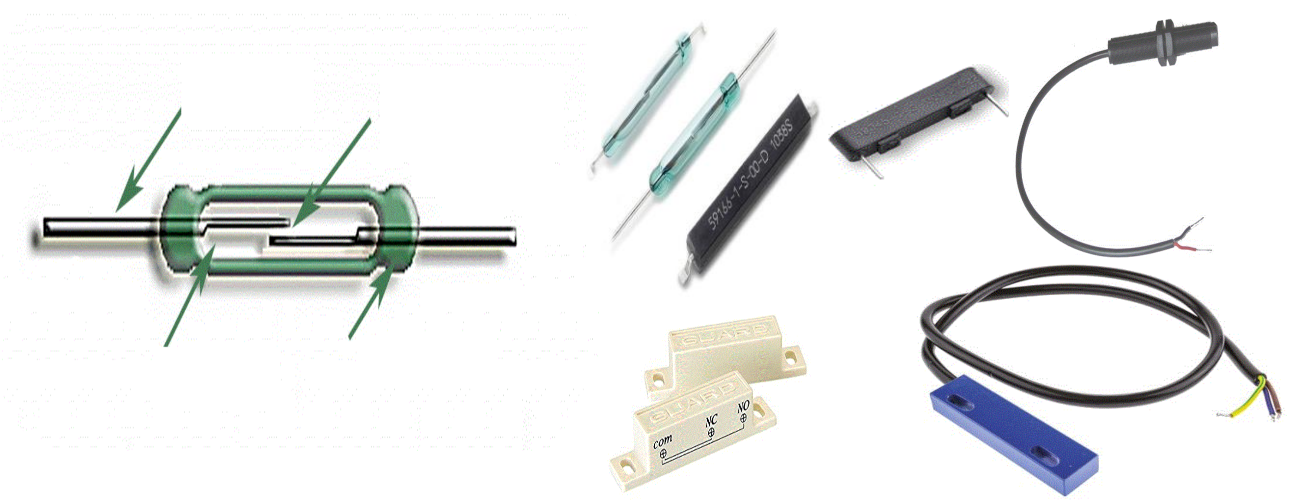


Fig4.14:

Functionally, these switches came to control the making and breaking of electric circuit, so structurally they may be of normally open, may be of normally closed, and may be combination of these two. All of these switches are activated or driven by either permanent magnetic field or current carrying coil created field (electromagmatic field). Their behavior depend upon the way the magnetic field moves toward them or leaves them.

To get an idea about the operation of reed switches, the following cases would be introduced:

Case 1: Normally open reed switch behavior under forward and backward movement of the permanent magnet with the movement direction is perpendicular to the switch plan (Fig.4.15).

When the permanent magnet reaches point B, the reed contacts close by snap close action because the field force exceeded the Pull-in force. The returning back to point A opens the contacts when field force drops below the pull-out value.

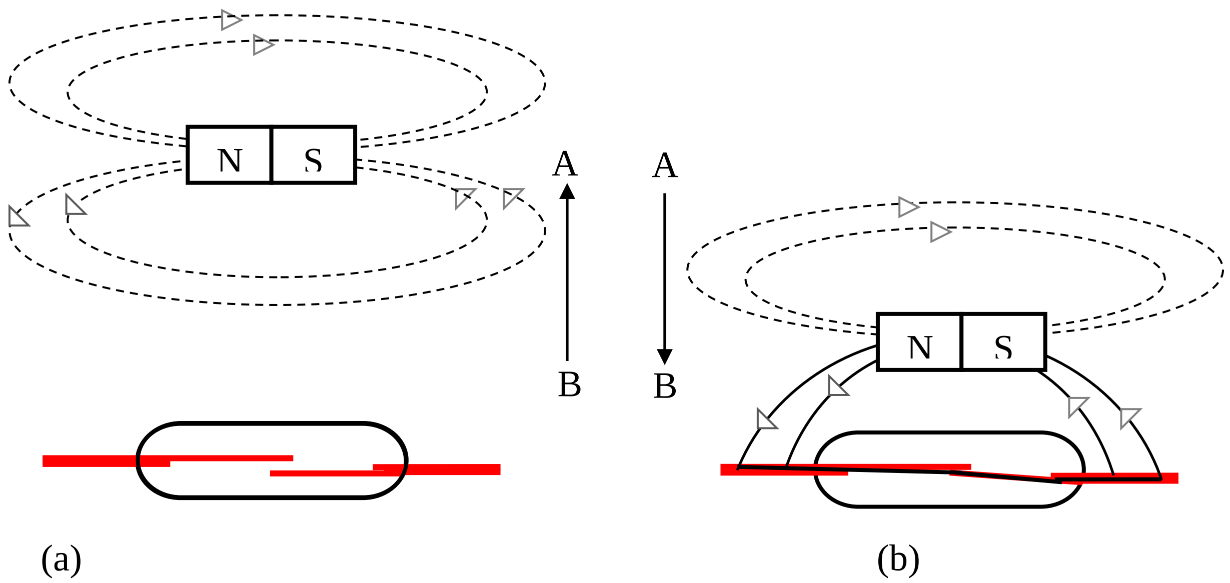


Fig.4.15: Normally open reed switch . (a): Magnet is far. (b): Magnet is close.

Case 2: : Normally close reed switch behavior under forward and backward movement of the permanent magnet with the movement direction is perpendicular to the switch plan (Fig.4.16).

When the permanent magnet reaches point B, the reed contacts open because the field force cancels that of the built-in magnet. The returning back to point A closes the contacts.

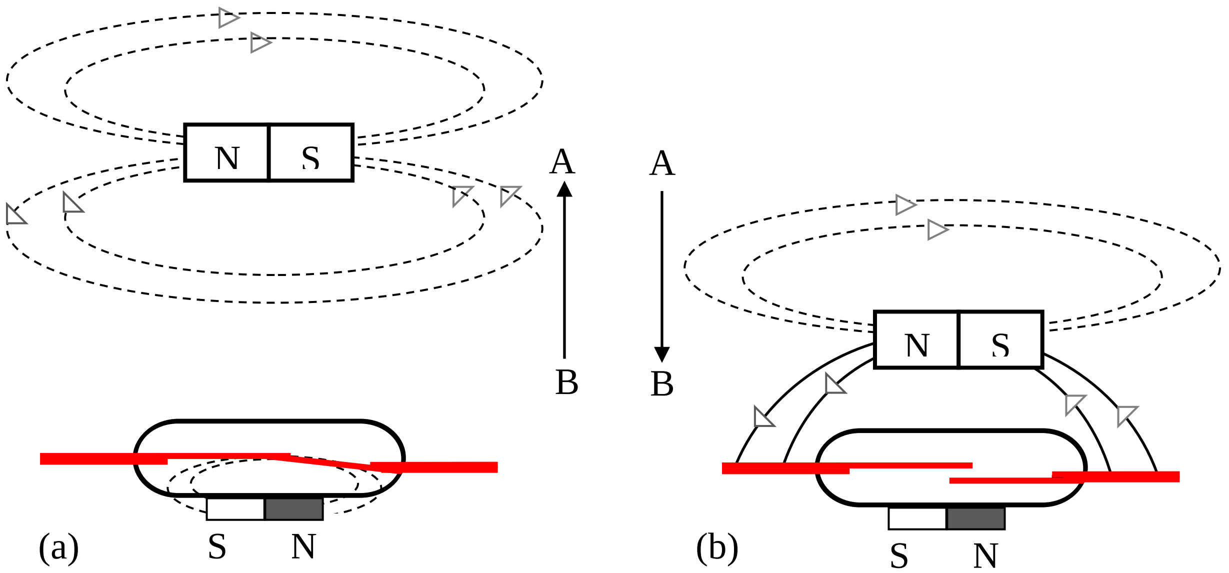


Fig.4.16: Normally close reed switch . (a): Magnet is far. (b): Magnet is close.

4.1.5 Pressure Actuated Switches

Pressure sensors are used to ensure the correct or safety operation of an industrial applications like cooling system in which the compressor discharge side pressure should not exceeds a preset high pressure level and at the same time the compressor suction side pressure should not drops below a preset low pressure level.

Pressure sensor is a pressure-to-displacement converter (like Bourdon tubes, Bellows and diaphragms) followed by mechanical momentary type limit switch. Bellows and diaphragm types are widely used . Bellow type is used for low pressure applications where as diaphragm type is suitable for high pressure applications. With any one of them, the pressure change causes the displacement of the bellow or diaphragm in the upward or downward direction (depends on the pressure change direction) which in turn push or release the plunger of the momentary limit switch . When the displacement reaches the set point, the limit switch contacts are activated (Fig4.17).

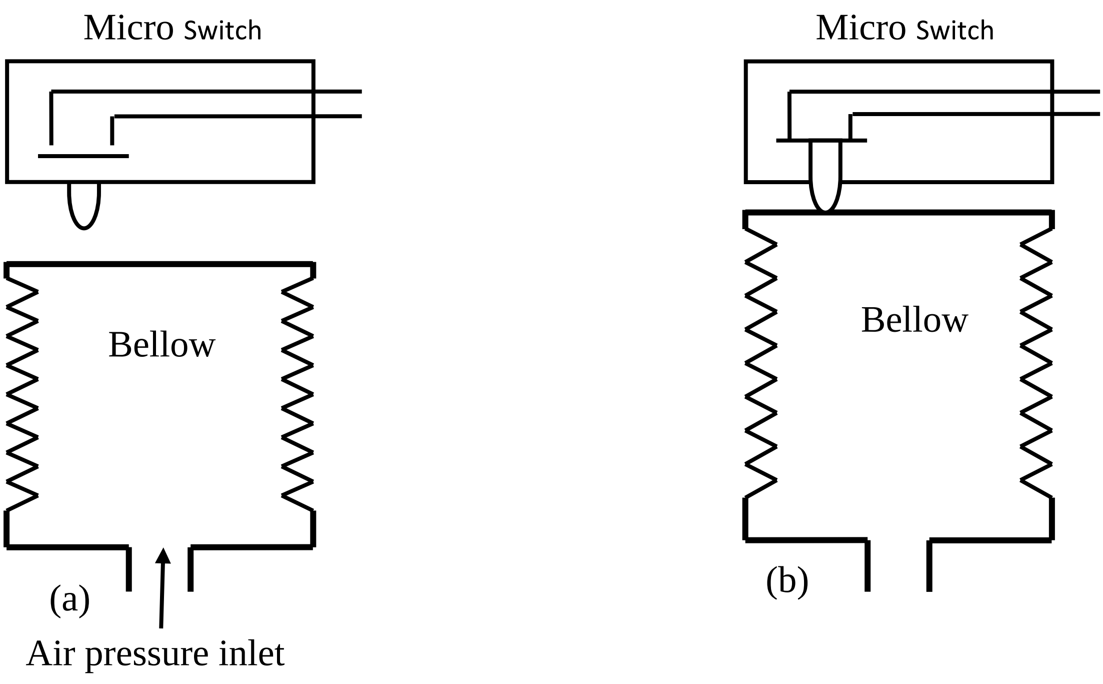


Fig.4.17: Bellow type switch. (a): Pressure is less than P_S (b): Pressure is greater than P_S

4.1.6 Temperature Sensors

Temperature sensors or commonly called thermostats are temperature actuated switches. They are designed to make or break an electrical contact when their designated temperature is reached. There are two popular types of these switches, the bi-metallic and the volatile liquid driven thermostats.

Bi-Metallic Thermostat

These are derived from the facts that when materials are heated they expand and the high expansion coefficient material expands more than that with lower expansion coefficient. From this origin, this type of binary switch is constructed by bounding two strips of different materials with different coefficients of expansion. The lower coefficient strip is placed on the top of the strips assembly to allow the bending or shrinking . The assembly bends upward for an increase in temperature above the setting point and shrinks causing a downward bending for temperature reduction. Figure 4.18 details these two movements.

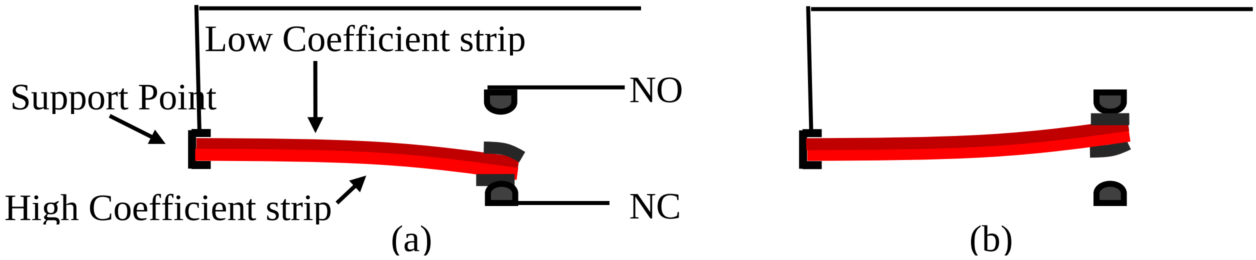


Fig.4.18: Bi-Metallic Thermostat. (a): Cool state. (b): Heated state.

Volatile Liquid Operated Thermostat

The construction of this thermostat had been extracted from the fact that volatile liquids try to occupy volumes proportional to their temperatures. As the temperature increases these volatile liquids expand causing a pressure on their containers and the reveres gives the reverse. From this, this type of thermostat is built by allowing the volatile liquid to expand or shrink in a bellow through capillary tube ended with a bulb in contact with the temperature source. Figure 4.19 displays a schematic diagram of such type.

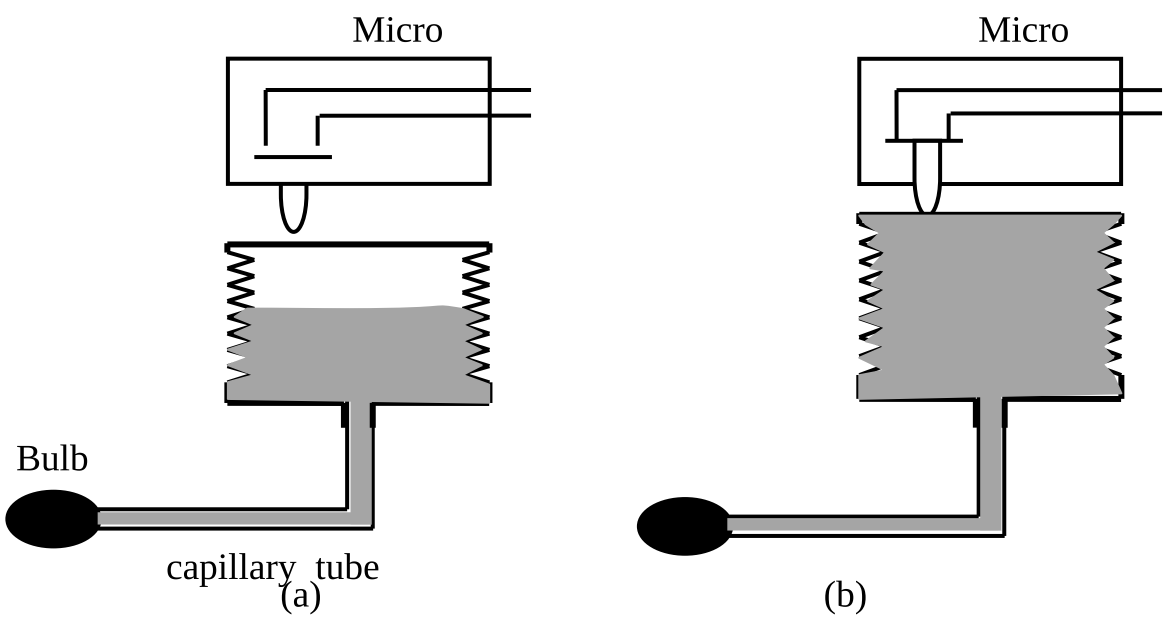
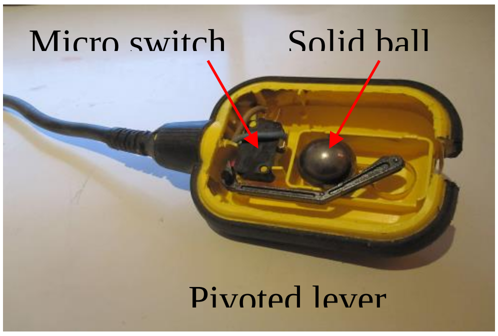


Fig.4.19: Bellow type switch. (a):Low temperature (b): High temperature

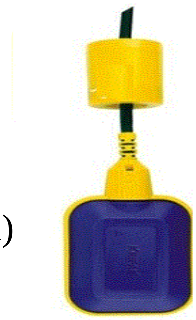
4.1.7 Liquid Level Sensors

Liquid level sensors which are also called float sensors are used to monitor the level of a liquid. They are made up of micro limit switch and level sensitive mechanism to control the operation of the micro switch. What is shown in figure 4.20 is one type of such switches. It consists of micro switch, solid ball, and pivoted lever encapsulated in one floating encloser in addition to adjustable length suspending thread. The operating mechanism of such switch is that when the liquid level drops below the minimum specified level (figure 4.21a), the floating encloser is hanged, the micro switch plunger is released, and the normally closed contacts are bridged to close the electrical circuit. When the liquid height rises beyond the free length of the thread, the floating encloser turns up down (figure 4.21b), the solid ball pushes the pivoted lever against the switch plunger, and the plunger under press takes the bridge away from the contacts to stop or open the electrical circuit.



Internal structure of Float level sensor.

Fig.4.20: Float level sensor.



(a)

(b)

Fig.4.21: Float sensor extreme positions. (a): Lower position: (b) : Upper position.

4.1.8 Digital Output Hall Effect Sensors

4.1.8.1 Hall Effect Concept

In 1870 Edwin Hall stated that when a flat current-carrying conductor of thickness “t” and carrying current “I” is placed in a magnetic field with flux density B, a voltage will be generated perpendicular to both the current and the field (Fig.422). This Hall called voltage is expressed as :

$V_H = K_H.B.I/t$ where K_H stands for Hall coefficient K_H which is directly proportional to the product of the charge mobility and conductor’s resistivity, B represent the field flux density, I is the current flowing through the flat conductor, and t is the conductor thickness.

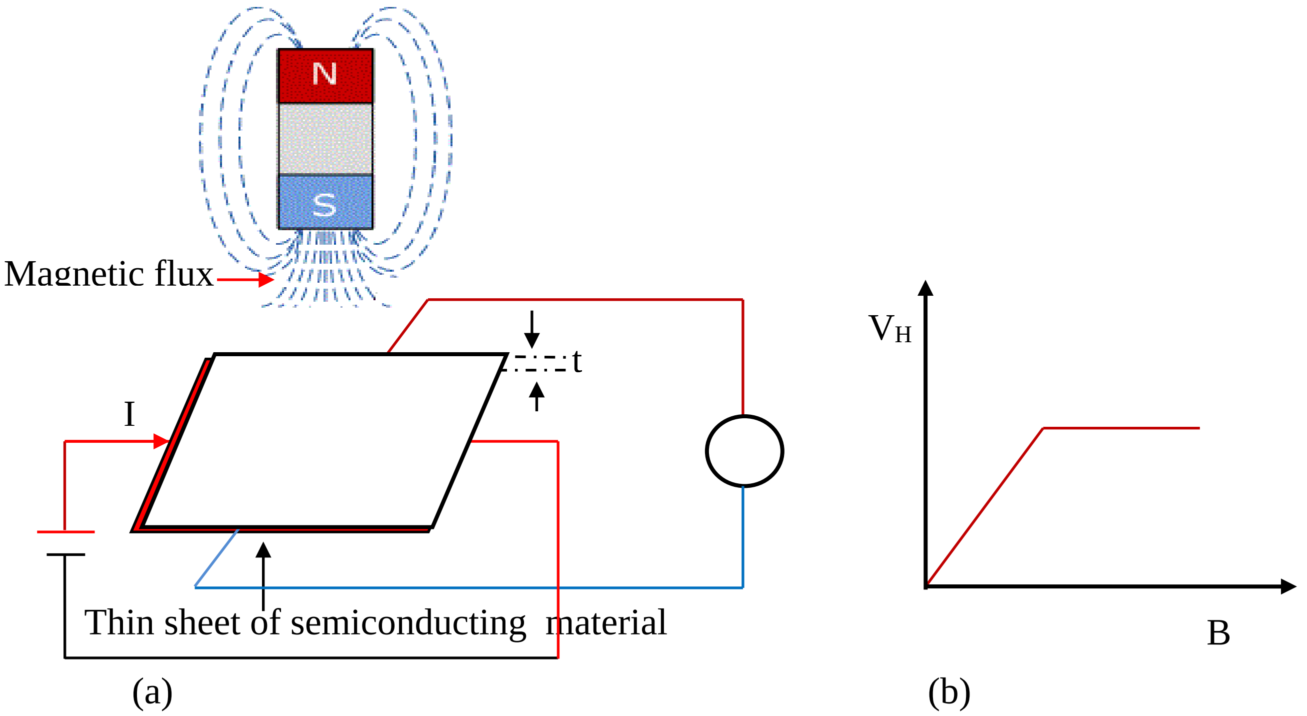


Fig.4.22:Hall effect principle. (a): Circuit configuration. (b): B-V_H characteristics.

According to this equation, Hall effect is negligibly small in most of the metallic conductors and also insulators because in the former the resistivity is low and in the later the charge mobility is too low. Hall effect is noticeable in some semiconductors like Indium antimonide in which K_H approaches 20 V/T.

4.1.8.2 Hall Effect Proximity Switches or Sensors Basic Structure

As stated in Fig.4.23, Hall effect proximity switches or sensors basically consist of:

- DC voltage regulator to provide well regulated dc voltage source for Hall element and also to enlarge the external dc voltage required to supply the sensor as whole.
- Thin piece of semiconducting material carrying constant current to detect the presence of magnetic field and generate Hall voltage.
- Differential amplifier to boost the Hall voltage from its micro volt range to applicable range.
- Schmitt-trigger with built in hysteresis connected to the amplifier to generate the two output states "0" and "1" of the senor.
- Switching transistor to enable the sensor to drive wide range of fans.

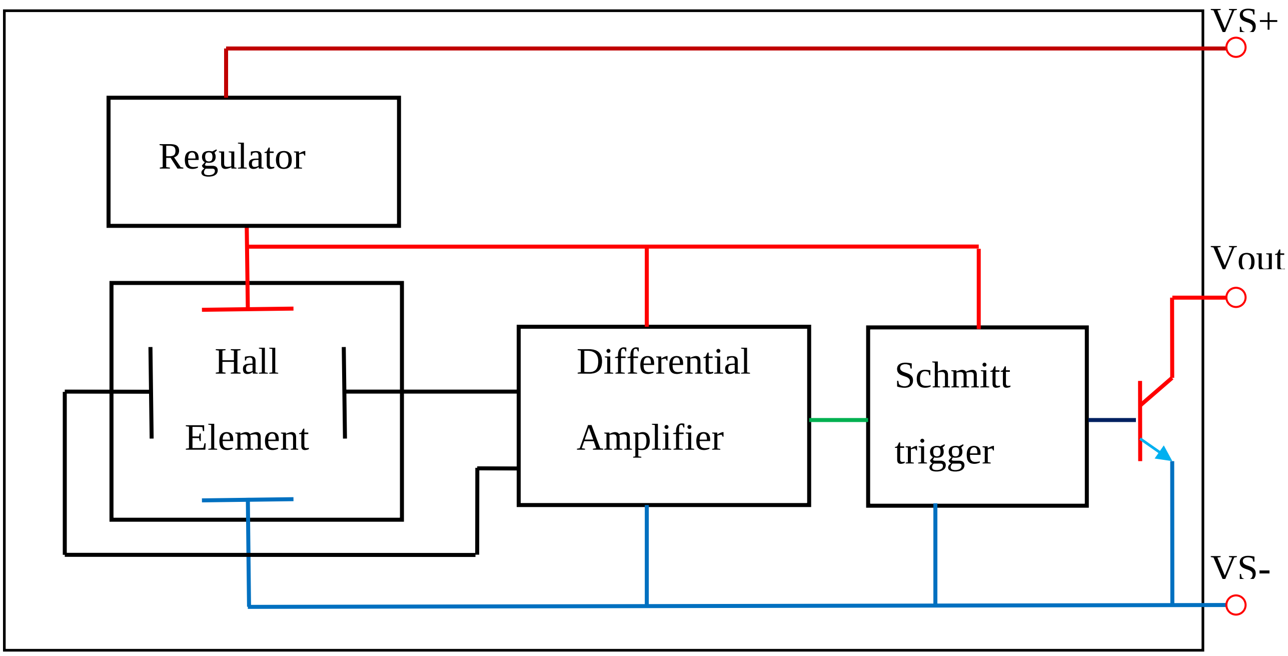


Fig.4.23: Digital output Hall effect sensor.

4.1.8.3 Hall Effect Proximity Sensors Operation

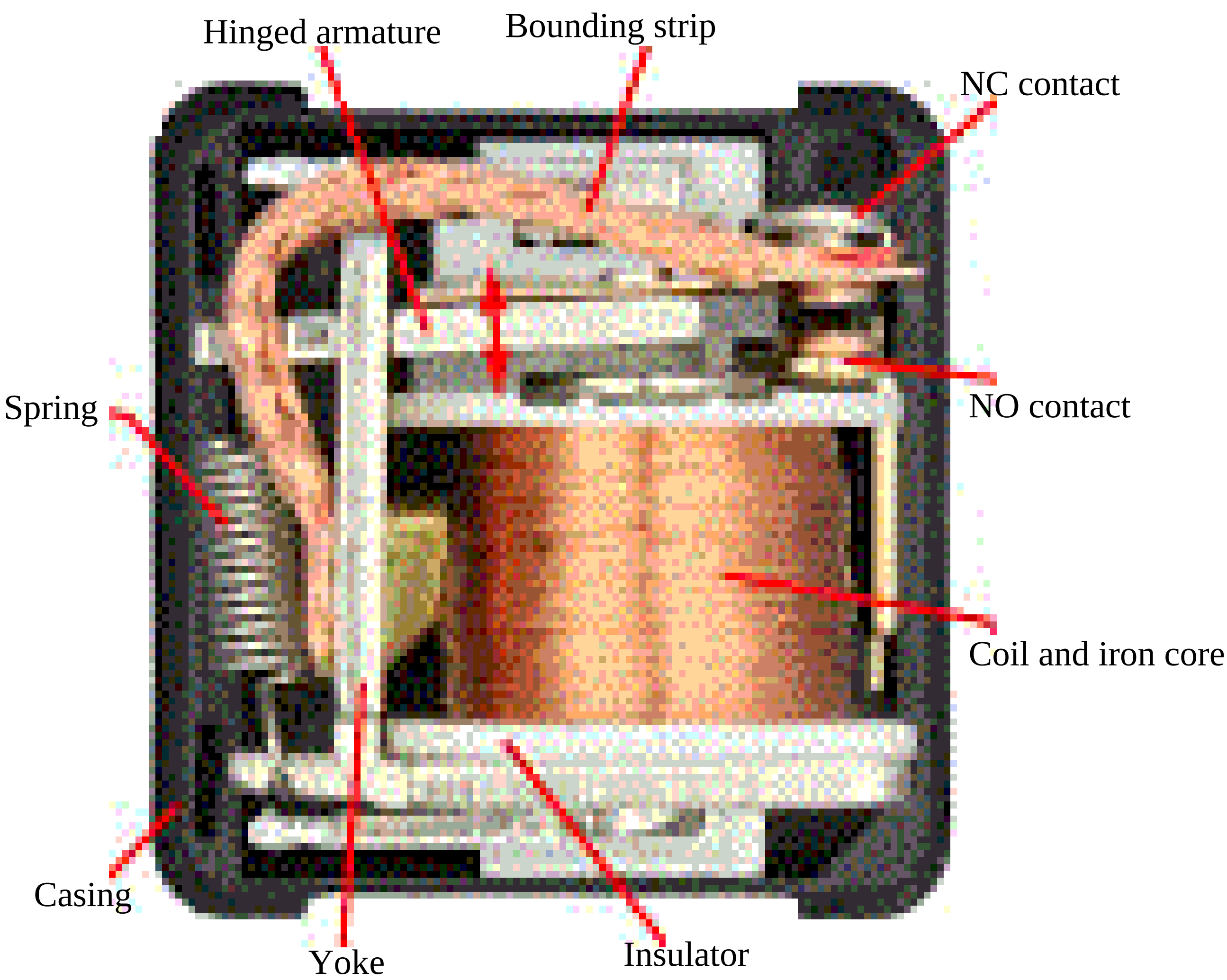
Digital output Hall effect sensors are designed to be in the "OFF" state when there is no magnetic field passing through them and turn "ON" when subjected to magnetic field with sufficient magnetic flux density and correct polarity.

4.2: Actuators

Actuators are the output devices that are responsible to implements the actions decided by the controllers or transform the actions into the forms the process machinery can understand. Actuators are subdivided into electromagnetic output devices and solid state output devices.

4.2.1 Electromagnetic Relays

The electromagnetic relays are magnetic actuated switches operated by relatively small amount of electric current and capable to switch on/off much larger currents. They are still used as an auxiliary device to switch on/off the field devices. The electromagnetic relay consists of a multi-turn coil, wound on an iron core, to form an electromagnet. When the coil is energized, by passing current through it, the core becomes magnetized as long as the excitation source is present. The magnetized core attracts the iron armature. The armature is pivoted which causes it to operate one or more sets of contacts. When the coil is de-energized the armature and contacts are released. Each relay consists of magnetic coil, movable armature, restraining spring, fixed set of electrical contacts, and movable set of electrical contacts (Fig4.23).



Fig,4.23: Magnetic Relay's Components,

Figure 4.24 shows an illustrative drawing for the electromagnetic relay construction and its contacts configuration when its coil is excited and when its coil is not excited. As it is shown in the figure, exciting the coil pulls down the movable armature, disconnect the movable contacts from the fixed normally closed contacts and connects them to the fixed normally open contact. The reverse occurs on de-energizing the relay coil. The relay's contacts are usually rated between 5 and 10 amperes. The coil possible voltage ratings are 12, 24, 48, 120, 220 VDC or VAC. Also they come with different number of terminals (Fig.4.25).

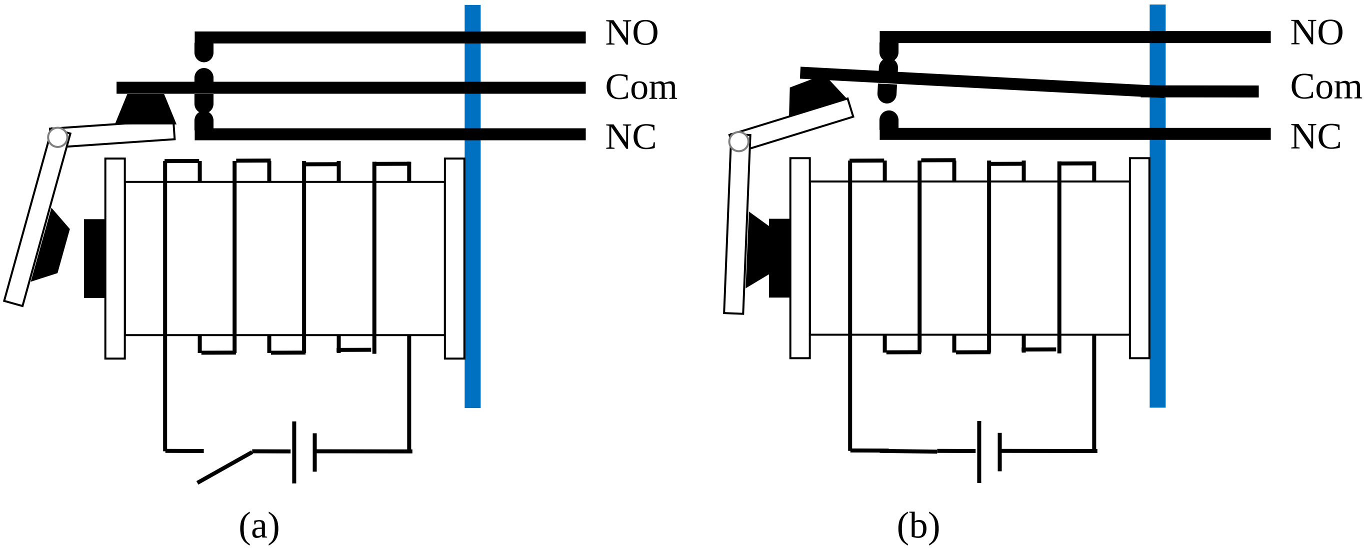


Fig.4.25: Relay behavior. (a) : The coil is de-energized (b): The coil is energized

Fig 4.25: Symbols of relays :

4.2.2 On Delay Relays

On delay relays are also called on delay timers. Functionally they are identical to the normal electromagnetic relays except that they are provided with a certain types of contacts close delay mechanism. In general they are a combination of normal electromagnetic relays and delay timing units. The timing delays unit may be thermal, may be mechanical, may be pneumatic, and may be electronic. With any type of on delay relays the required delay time should be set before energizing the relay power terminals. After power application, the movable contacts continue keeping contact with the fixed normally closed contacts (NCs) for an extra time period equals to the selected preset time then after the passage of that time, they move toward the fixed normally open contacts and make contact with them. Deenergizing the unit power terminals returns the movable contacts to their position when the relay is de-energized. Fig4.27 states the behavior of the on delay relay contacts under the energization and de-energization states. Fig.4.28 display symbol of market available timing units.

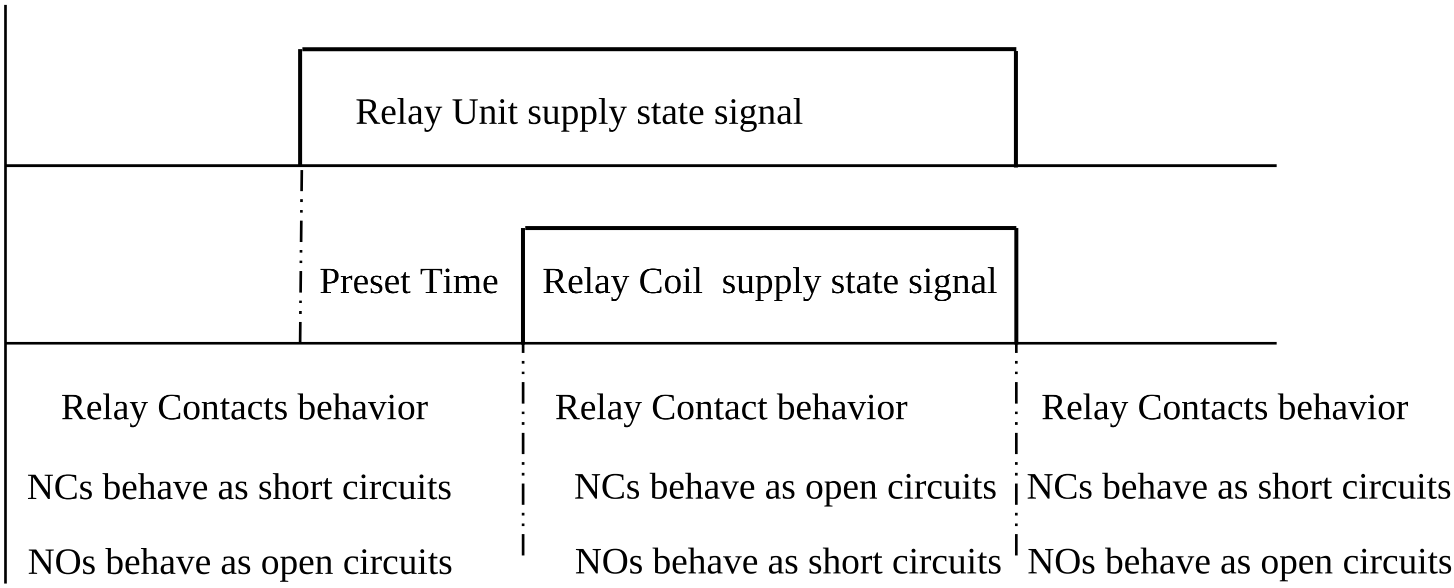


Fig.4.27: ON delay relay behavior.

(a)

(b)

Fig.4.28: Symbol of timing units. (a): Stand alone.

(b):Mounted on the top of magnetic contactors

4.2.3 Off Delay Relays

Off delay relays are also called off delay timers. Functionally they are identical to the normal electromagnetic relays from the point of view of making and breaking electrical circuits using normally open contacts and normally closed contacts. Their only difference is that they are provided with a certain types of contacts open delay mechanism. In general they are a combination of normal electromagnetic relays and off delay timing units. As it is the case with on delay relays, in off delay relays the required off delay time should also be set before energizing the relay power terminals. After power application, the movable contacts directly move toward the fixed normally open contacts and make contacts with them. The time the power is switched off, the timing functions start running, as long as the elapsed time is less than the preset one, the normally open contacts stay in contact with the movable ones. Once the elapsed time exceeds the preset one the movable contacts leaves the normally open ones and creates contact with the normally closed contacts (NCs). Fig4.29 states the behavior of the off delay relay contacts under the energization and de-energization states. Fig.4.30 display two types of market available off delay timing units.

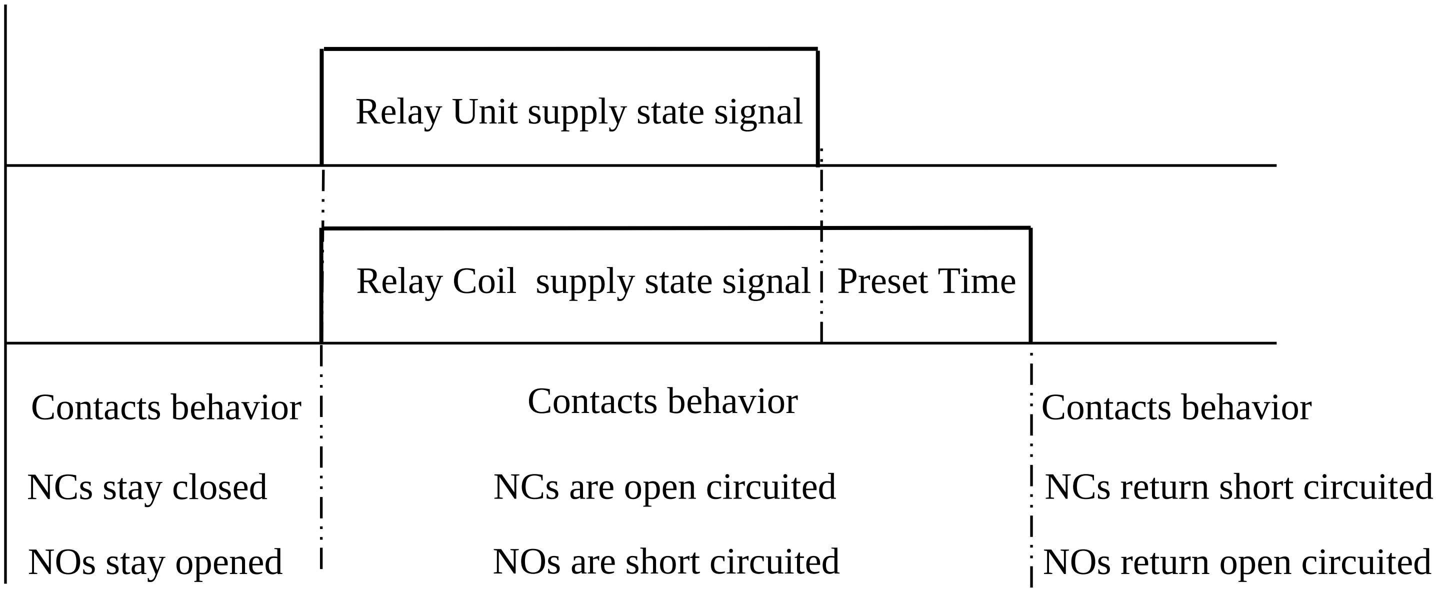


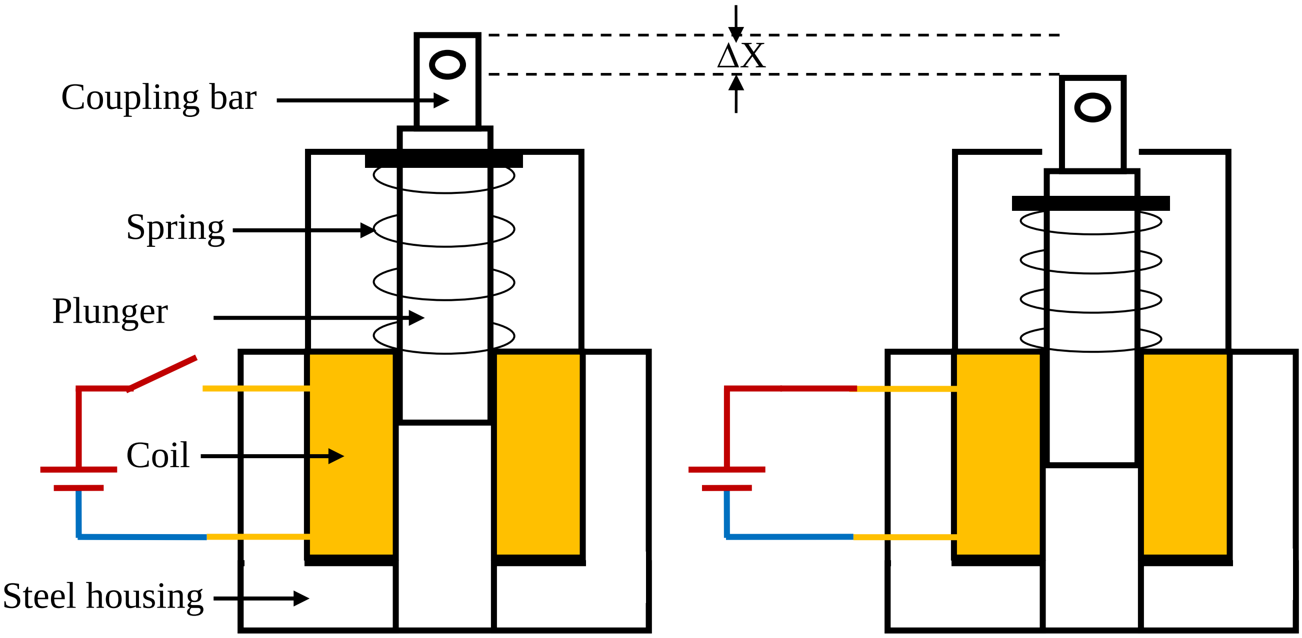
Fig.4.29: Off delay relay behavior.

(a) (b)

Fig.4.30: Samples of off delay timers. (a): Standalone one. (b) : Contactor top mounted one

4.2.4 Solenoid

The solenoid is an electromagnetic device used to convert an electrical signal (voltage or current) into linear mechanical motion. As it is evident from schematic diagram shown figure 4.31 the solenoid consists of coil surrounding movable iron core (plunger) and one spring assembly . The plunger is standing on the spring. The spring function is to keep the plunger away from the magnetic circuit center. Power application to the solenoid terminal creates a magnetic force opposing that exerted by the spring. This magnetic created force nears the movable plunger to the center of the magnetic circuit (middle of the coil). Deenergizing the coil enables the spring to upward moves the plunger after the disappearance of the magnetic force . Fig.4.32 shows samples of real solenoids.



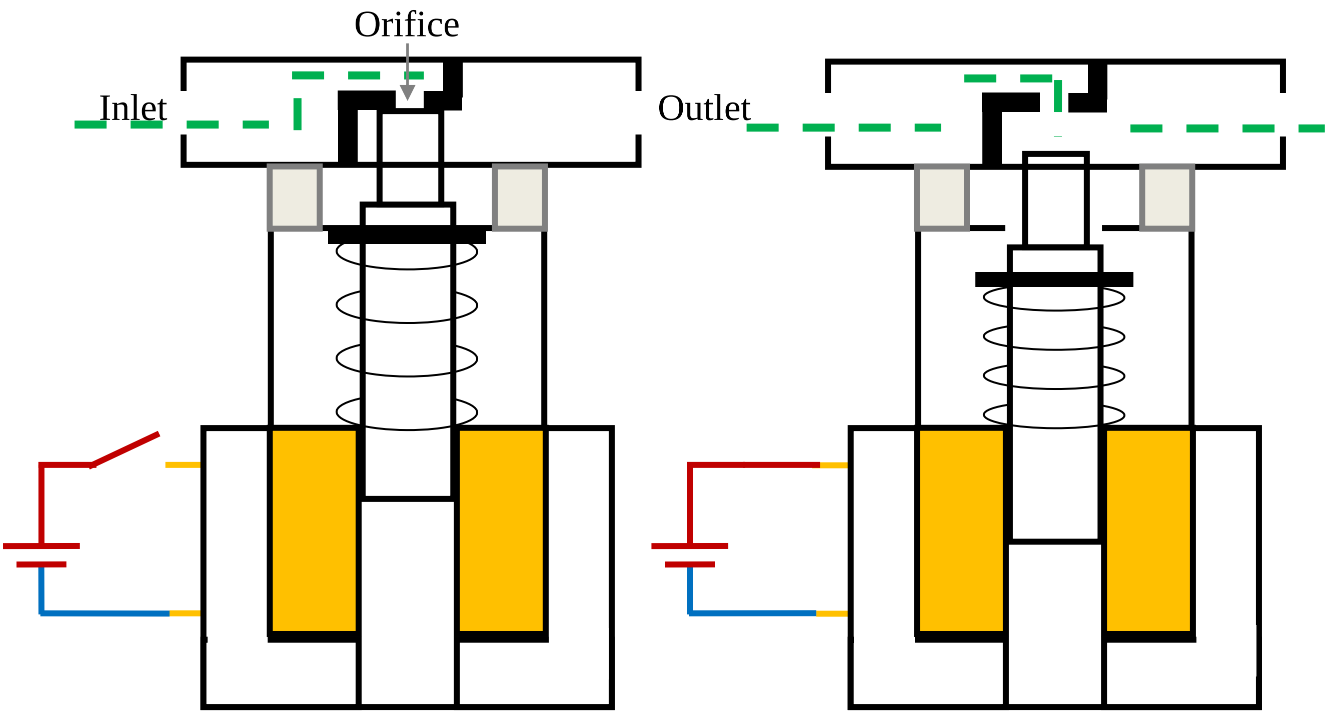
(a) (b)

Fig.31: Solenoid behavior. (a) : OFF state. (b): ON state

Fig.4.32: Symbols or real solenoids

4.2.4.5 Solenoid Valves

Solenoid valves are a combinations of solenoids and valve assemblies . As can be seen from figure 4.33, the solenoid function is to control the opening and closing of an orifice inside the valve assembly. Power application to the solenoid power terminals pulls down the plunger, opens the orifice, and allows the liquid to flow from the inlet to the outlet. Power removal de-energizes the solenoid coil, allows the spring to upward moves the plunger, and finally closes the orifice and blocks the liquid or gas flow. Fig.4.34 shows symbols of solenoid valves.



(a) (b)

Fig.34: Solenoid Valve behavior. (a) : OFF state. (b): ON state

Fig4.35: Examples of real solenoid valves.

4.2.6 Magnetic Contactors

Magnetic contactors are special type of electromagnetic relays. They are designed to carry heavy current, their current rating may ranges from 10 A to 2000A. To conduct and interrupt heavy currents, the contactors are provided with spark extinction mechanism to let the contactors contacts make and break the heavy currents without damage. The pictures in figure 4.36 give an idea about the construction of this switching devices in addition to its behavior under the powered and unpowered states. Fig.4.37 display examples of industrial magnetic contactors.

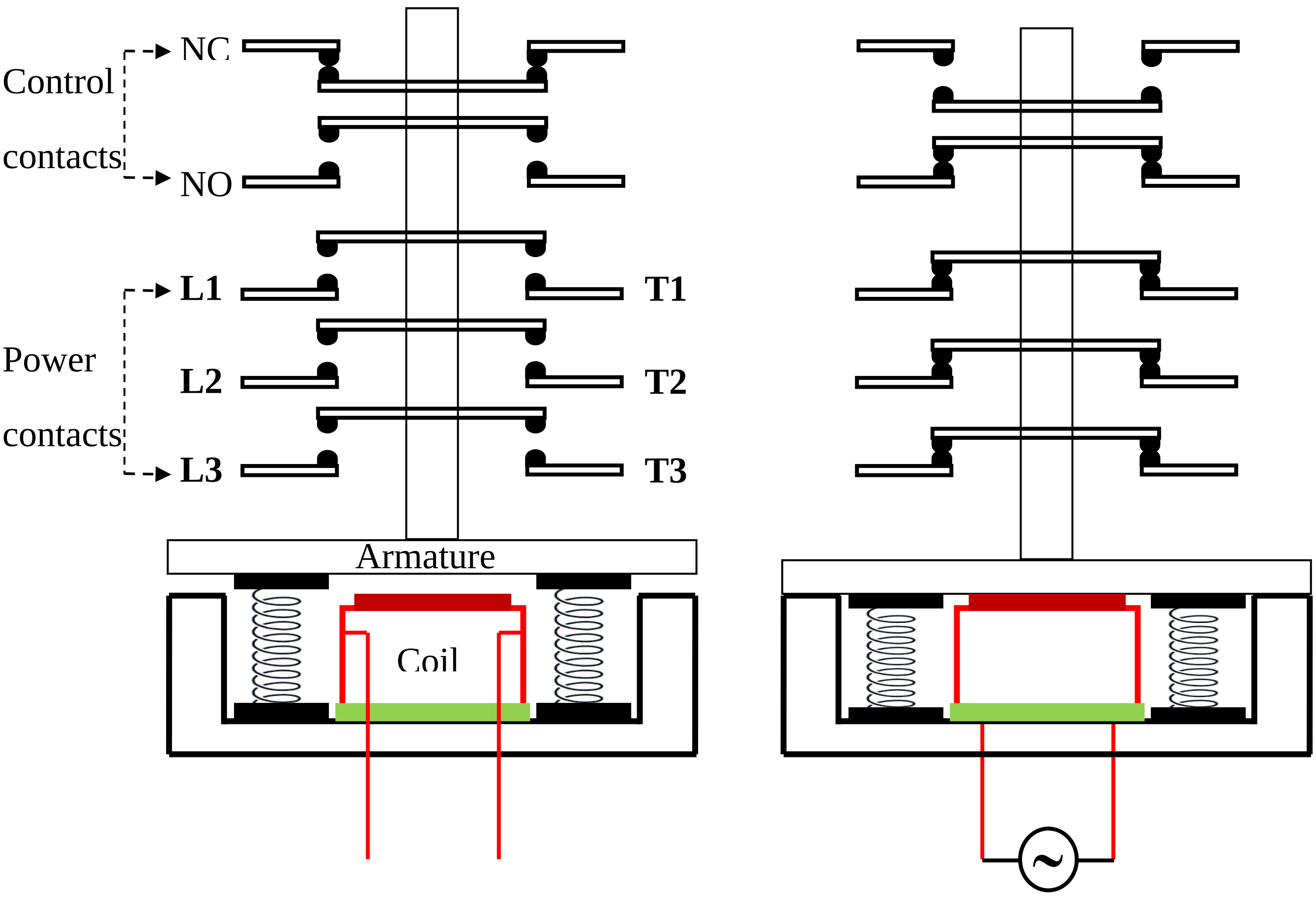


Fig.4.36: Basic construction of magnetic contactor. (a): OFF state. (b): ON state

Fig.4.37: Examples of industrial used magnetic contactors.

4.2.7 DC solid state relays

DC solid state relays are power electronics switching devices in which small control signals (3-32VDC) control large DC load currents. Figure 4.38 introduces the basic functional blocks of this contact less relay. As it is sound from the figure it is free from any mechanical part and so it can be used for high switching rates as compared to the electromagnetic one witch can only be used with relatively small switching rate applications. Here the application of the control signal creates conducting bridge between the power source and the load via the power transistor low forward resistance. Blocking the control signal increases the transistor resistance connected in series with the load (device reverse resistance) and this reduces the load current into negligible value. The Solid state relays can be driven by different devices because of its control voltage wide operating range. Fig.4.39 shows symbols of these relays.

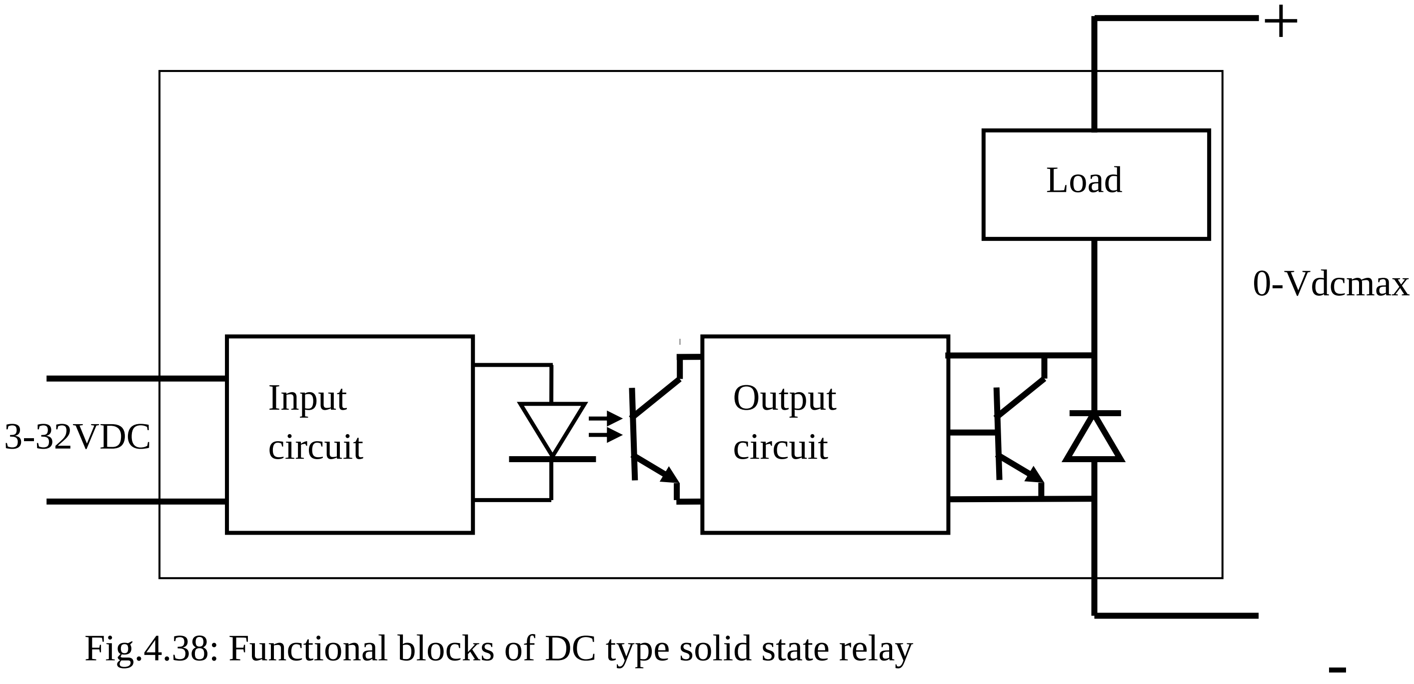


Fig.4.38: Functional blocks of DC type solid state relay

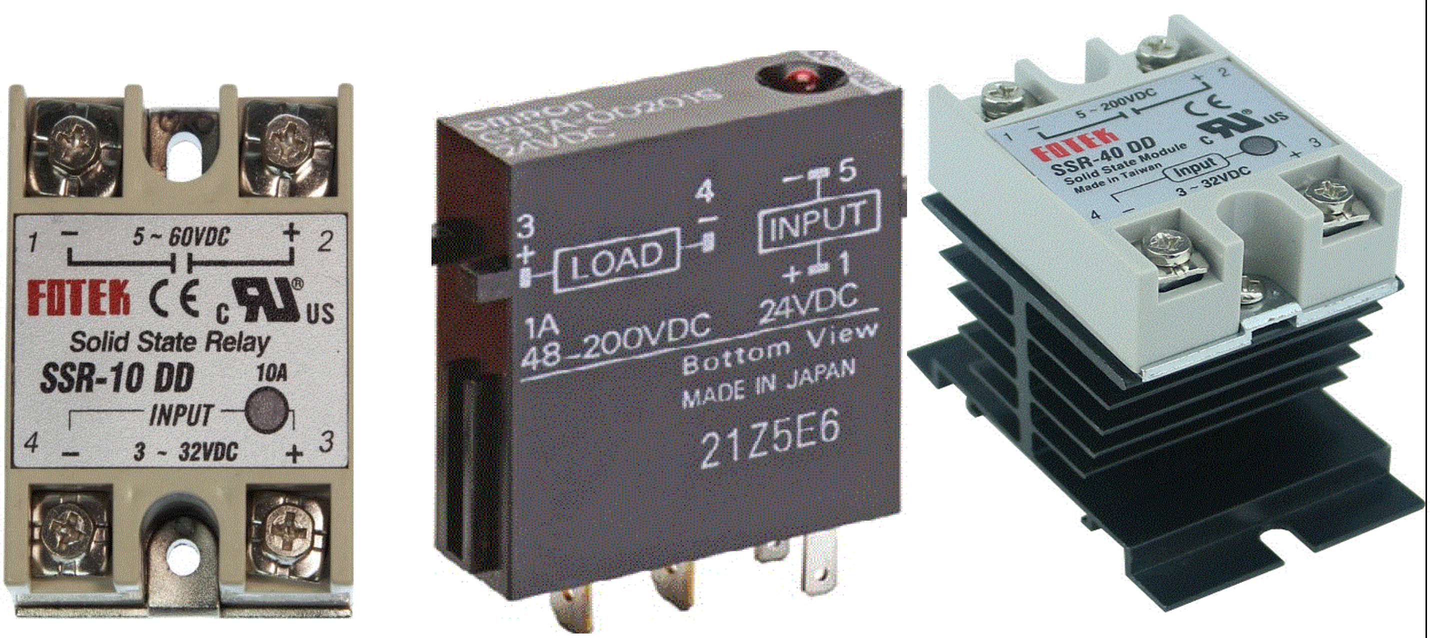


Fig.4.39: Example of DC solid state relays.

4.2.8 AC solid state relays

AC solid state relays are power electronics switching devices used to control the switching of heavy AC load currents using either two antiparallel connected thyristors or triac switches . Here the firing signal and hence the heavy AC load current is also controlled by small control signals (3-32VDC). Figure4.40 shows the basic functional blocks of this mechanical parts free relay. Here the application of the control signal creates conducting bridge between the power source and the load via the power semiconductor device low forward resistance. Blocking the control signal stops the firing pulses and leads to negligible current flow in the load or in other word increases the power switch resistance connected in series with the load into very high value. Samples of ac solid state relays are shown in fig,4.41.

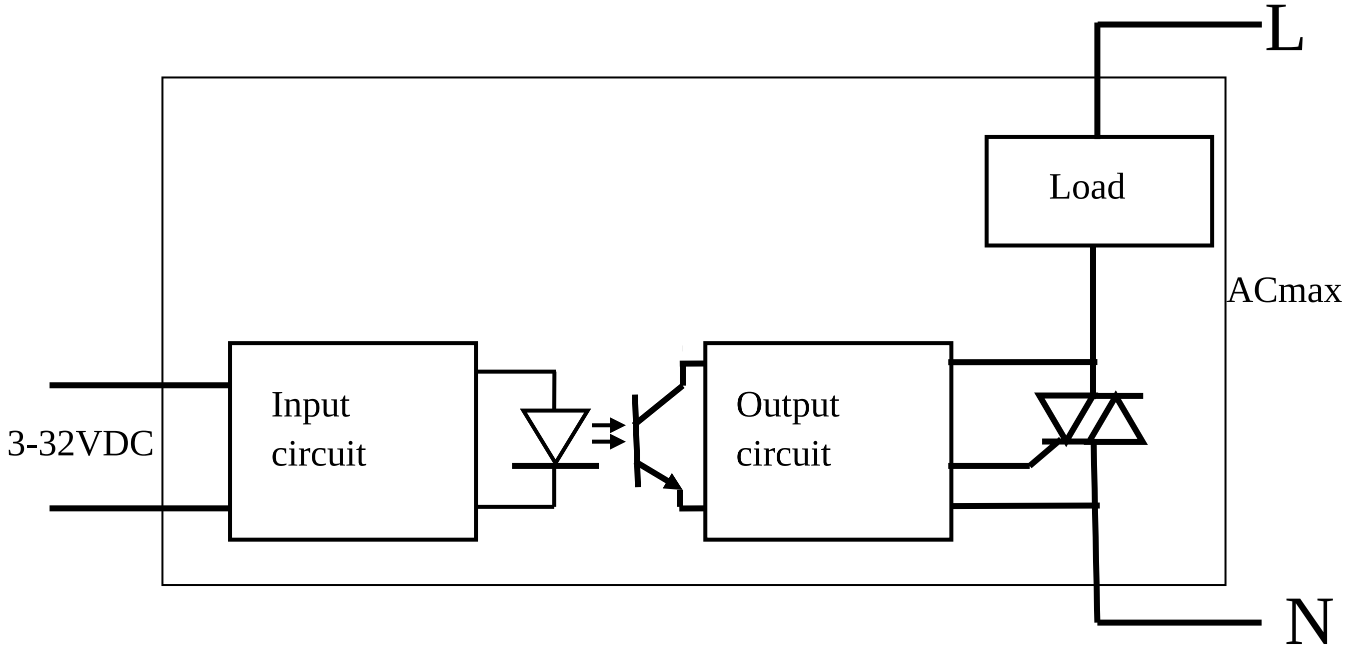


Fig.4.41: Functional blocks of triac type solid state relay

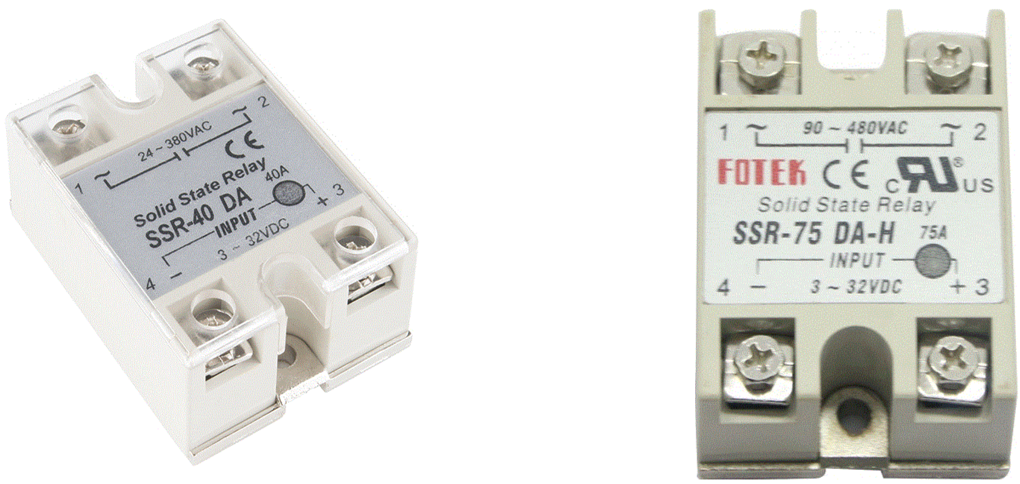


Fig.4.42: Symbols of ac solid state relays