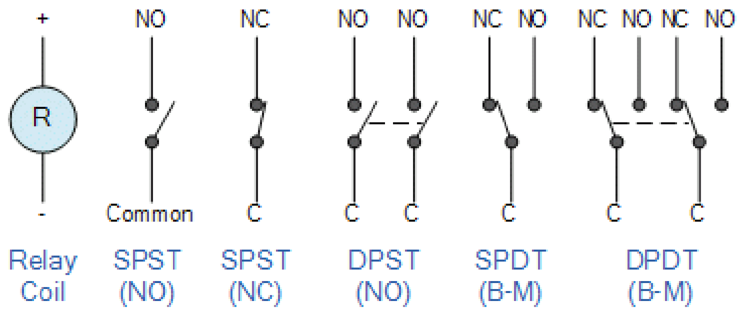


Electrical Relay

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

Thus far we have seen a selection of *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 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.

For example, a relay is a binary actuator as it has two stable states, either energised and latched or de-energised and unlatched, while a motor is a continuous actuator because it can rotate through a full 360^{o} motion. The most common types of actuators or output devices are **Electrical Relays**, **Lights**, **Motors** and **Loudspeakers**.

We saw previously that solenoids can be used to electrically open latches, doors, open or close valves, and in a variety of robotic and mechatronic applications, etc. However, if the solenoid plunger is used to operate one or more sets of electrical contacts, we have a device called a *relay*that is so useful it can be used in an infinite number of different ways and in this tutorial we will look at Electrical Relays.

Electrical Relays can also be divided into mechanical action relays called “Electromechanical Relays” and those which use semiconductor transistors, thyristors, triacs, etc, as their switching device called “Solid State Relays” or SSR’s.

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.

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".

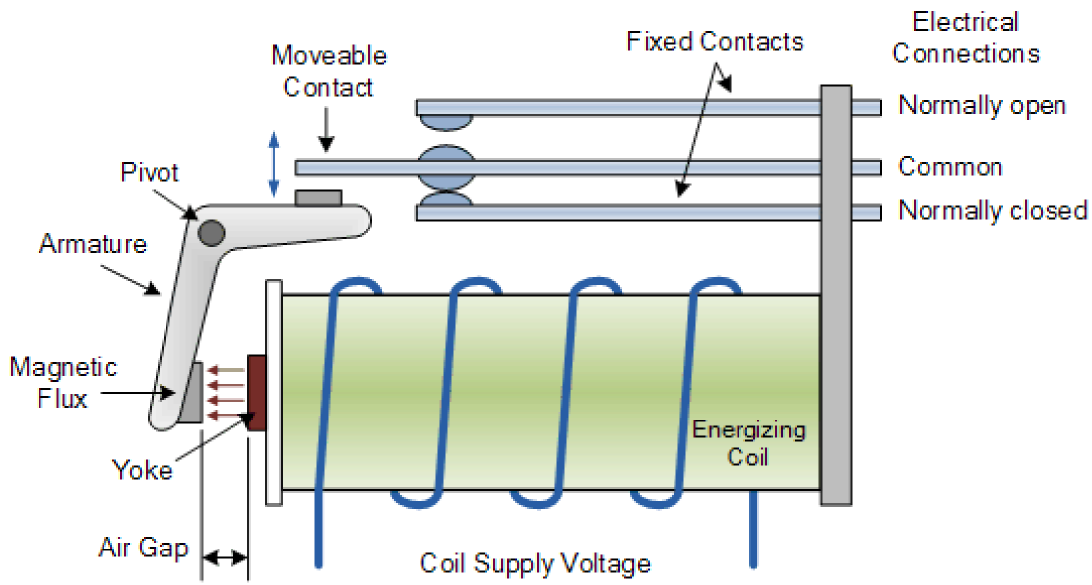
An Electrical Relay

In this tutorial about electrical relays we are just concerned with the fundamental operating principles of "light duty" electromechanical relays we can use in motor control or robotic circuits. Such relays are used in general electrical and electronic control or switching circuits either mounted directly onto PCB boards or connected free standing and in which the load currents are normally fractions of an ampere up to 20+ amperes. The relay circuit are common in Electronics applications.

As their name implies, 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.

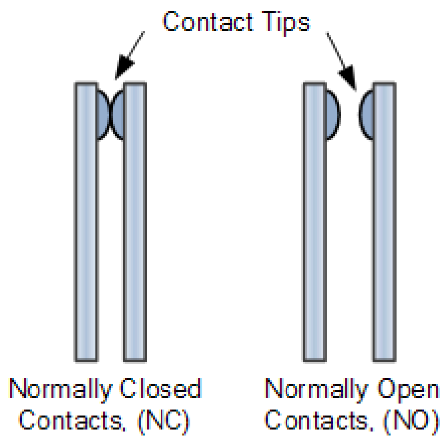
This iron core has both a fixed portion called the yoke, and a moveable spring loaded part called the armature, that completes the magnetic field circuit by closing the air gap between the fixed electrical coil and the moveable armature. The armature is hinged or pivoted allowing it to freely move within 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



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.



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.

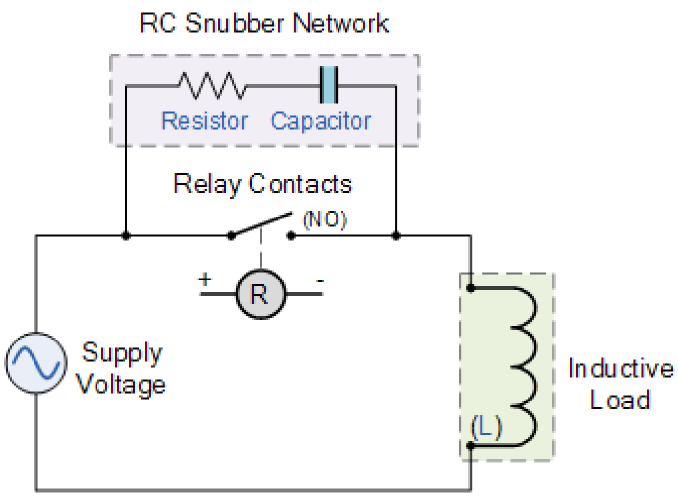
Platinum, Gold and Silver Alloys

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

Relay manufacturers data sheets give maximum contact ratings for resistive DC loads only and this rating is greatly reduced for either AC loads or highly inductive or capacitive loads. In order to achieve long life and high reliability when switching alternating currents with inductive or capacitive loads some form of arc suppression or filtering is required across the relay contacts.

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



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

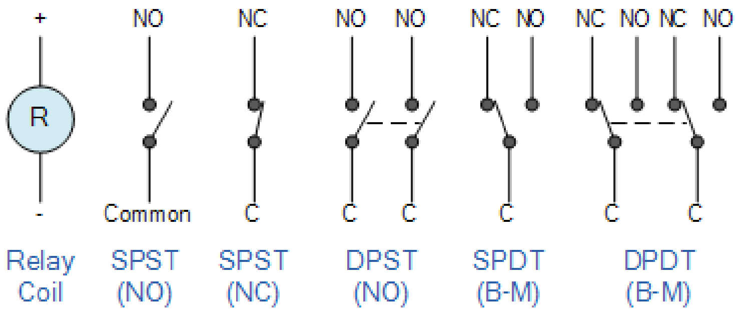
DPDT – Double Pole Double Throw

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.

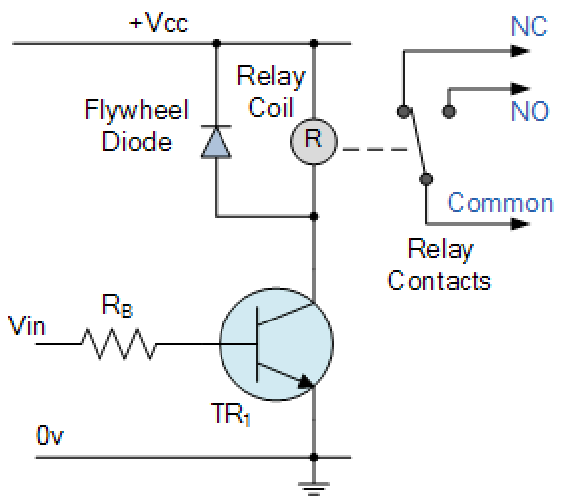
When both a make and a break set of contact elements are present at the same time so that the two contacts are electrically connected to produce a common point (identified by three connections), the set of contacts are referred to as "Form C contacts" or change-over contacts. If no electrical connection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

One final point to remember about using electrical relays. It is not advisable at all to connect relay contacts in parallel to handle higher load currents. For example, never attempt to supply a 10A load with two relay contacts in parallel that have 5A contact ratings each, as the mechanically operated relay contacts never close or open at exactly the same instant of time. The result is that one of the contacts will always be overloaded even for a brief instant resulting in premature failure of the relay over time.

Also, while electrical relays can be used to allow low power electronic or computer type circuits to switch relatively high currents or voltages both “ON” or “OFF”. Never mix different load voltages through adjacent contacts within the same relay such as for example, high voltage AC (240v) and low voltage DC (12v), always use separate relays for safety.

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).

As the current flows through the coil a self induced magnetic field is generated around it. When the current in the coil is turned “OFF”, a large back emf (electromotive force) voltage is produced as the magnetic flux collapses within the coil (transformer theory). This induced reverse voltage value may be very high in comparison to the switching voltage, and may damage any semiconductor device such as a transistor, FET or micro-controller used to operate the relay coil.



One way of preventing damage to the transistor or any switching semiconductor device, is to connect a reverse biased diode across the relay coil.

When the current flowing through the coil is switched “OFF”, an induced back emf is generated as the magnetic flux collapses in the coil.

This reverse voltage forward biases the diode which conducts and dissipates the stored energy preventing any damage to the semiconductor transistor.

When used in this type of application the diode is generally known as a **Flywheel Diode**, **Free-wheeling Diode** and even **Fly-back Diode**, but they all mean the same thing. Other types of inductive loads which require a flywheel diode for protection are solenoids, motors and inductive coils.

As well as using flywheel Diodes for protection of semiconductor components, other devices used for protection include **RC Snubber Networks**, **Metal Oxide Varistors** or **MOV** and **Zener Diodes**.

The Solid State Relay.

While the **electromechanical relay** (EMR) are inexpensive, easy to use and allow the switching of a load circuit controlled by a low power, electrically isolated input signal, one of the main disadvantages of an electromechanical relay is that it is a “mechanical device”, that is it has moving parts so their switching speed (response time) due to physically movement of the metal contacts using a magnetic field is slow.

Over a period of time these moving parts will wear out and fail, or that the contact resistance through the constant arcing and erosion may make the relay unusable and shortens its life. Also, they are electrically noisy with the contacts suffering from contact bounce which may affect any electronic circuits to which they are connected.

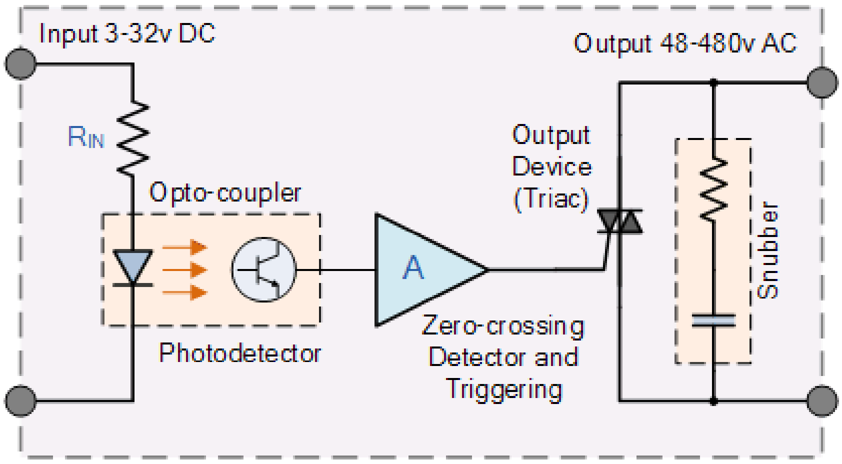
To overcome these disadvantages of the electrical relay, another type of relay called a **Solid State Relay** or (**SSR**) for short was developed which is a solid state contactless, pure electronic relay.

The solid state relay being a purely electronic device has no moving parts within its design as the mechanical contacts have been replaced by power transistors, thyristors or triac’s. The electrical separation between the input control signal and the output load voltage is accomplished with the aid of an opto-coupler type Light Sensor.

The **Solid State Relay** provides a high degree of reliability, long life and reduced electromagnetic interference (EMI), (no arcing contacts or magnetic fields), together with a much faster almost instant response time, as compared to the conventional electromechanical relay.

Also the input control power requirements of the solid state relay are generally low enough to make them compatible with most IC logic families without the need for additional buffers, drivers or amplifiers. However, being a semiconductor device they must be mounted onto suitable heatsinks to prevent the output switching semiconductor device from over heating.

Solid State Relay



The AC type Solid State Relay turns "ON" at the zero crossing point of the AC sinusoidal waveform, prevents high inrush currents when switching inductive or capacitive loads while the inherent turn "OFF" feature of Thyristors and Triacs provides an improvement over the arcing contacts of the electromechanical relays.

Like the electromechanical relays, a Resistor-Capacitor (RC) snubber network is generally required across the output terminals of the SSR to protect the semiconductor output switching device from noise and voltage transient spikes when used to switch highly inductive or capacitive loads. In most modern SSR's this RC snubber network is built as standard into the relay itself reducing the need for additional external components.

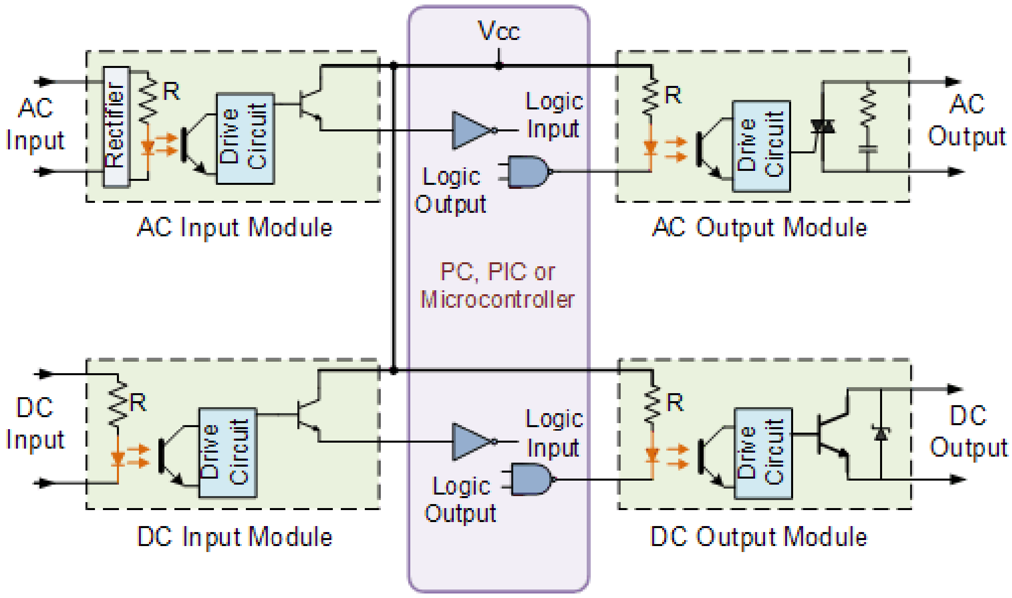
Non-zero crossing detection switching (instant "ON") type SSR's are also available for phase controlled applications such as the dimming or fading of lights at concerts, shows, disco lighting etc, or for motor speed control type applications.

As the output switching device of a solid state relay is a semiconductor device (Transistor for DC switching applications, or a Triac/Thyristor combination for AC switching), the voltage drop across the output terminals of an SSR when "ON" is much higher than that of the electromechanical relay, typically 1.5 – 2.0 volts. If switching large currents for long periods of time an additional heat sink will be required.

Input/Output Interface Modules.

Input/Output Interface Modules, (I/O Modules) are another type of solid state relay designed specifically to interface computers, micro-controller or PIC's to "real world" loads and switches. There are four basic types of I/O modules available, AC or DC Input voltage to TTL or CMOS logic level output, and TTL or CMOS logic input to an AC or DC Output voltage with each module containing all the necessary circuitry to provide a complete interface and isolation within one small device. They are available as individual solid state modules or integrated into 4, 8 or 16 channel devices.

Modular Input/Output Interface System.



The main disadvantages of solid state relays (SSR's) compared to that of an equivalent wattage electromechanical relay is their higher costs, the fact that only single pole single throw (SPST) types are available, "OFF"-state leakage currents flow through the switching device, and a high "ON"-state voltage drop and power dissipation resulting in additional heat sinking requirements. Also they can not switch very small load currents or high frequency signals such as audio or video signals although special Solid State Switches are available for this type of application.

In this tutorial about **Electrical Relays**, we have looked at both the electromechanical relay and the solid state relay which can be used as an output device (actuator) to control a physical process. In the next tutorial we will continue our look at output devices called **Actuators** and especially one that converts a small electrical signal into a corresponding physical movement using electromagnetism. The output device is called a Solenoid.